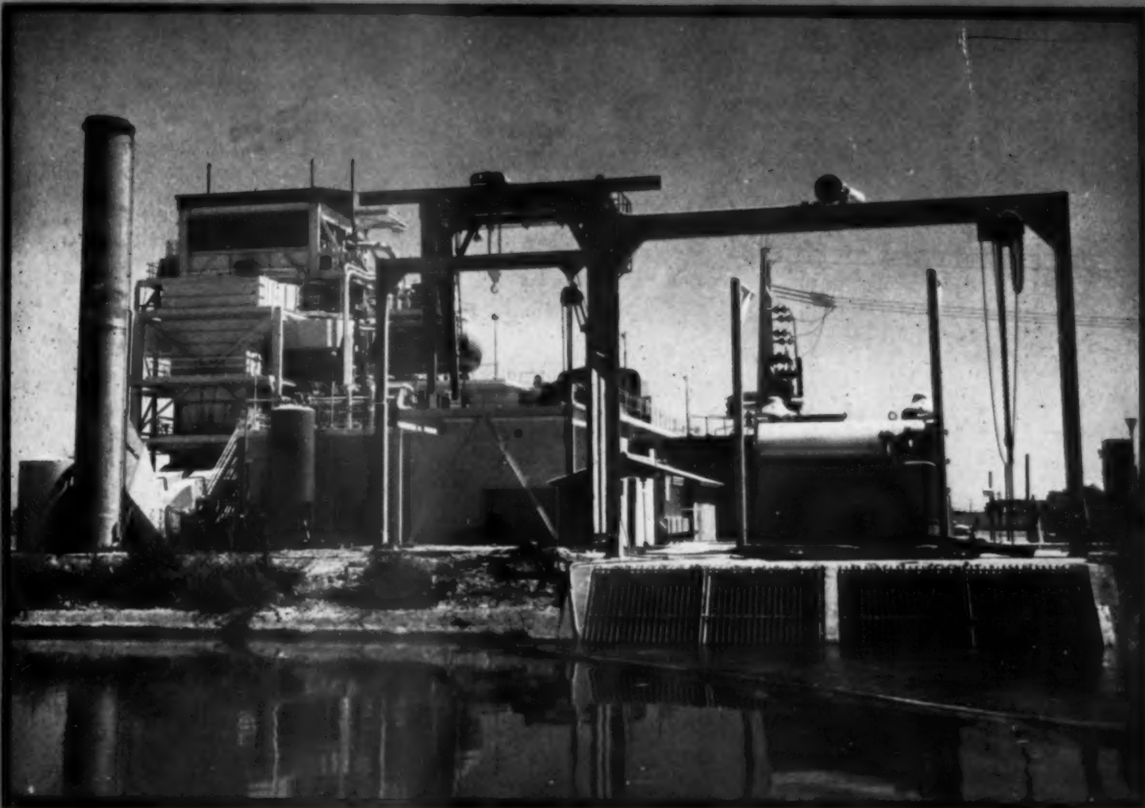
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

October 1952



Outdoor plant for Salt River Project; see page 48

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 24 **No. 4**

October 1952

Feature Articles

Editorials

Departments

COMBUSTION publishes its annual index in the June issue and is indexed regularly by Engineering Index, Inc.

Published monthly by COMBUSTION PUBLISHING COMPANY, INC., 200 Madison Ave., New York 16
A SUBSIDIARY OF COMBUSTION ENGINEERING-SUPERHEATER INC.
Joseph V. Santry, President; Charles McDonough, Vice-President; H. H. Berry, Secretary and Treasurer
COMBUSTION is sent gratis to engineers in the U. S. A. in charge of steam plants from 500 rated boiler horsepower up and to consulting engineers in this field. To others the subscription rate, including postage, is $3 in the United States, $3.50 in Canada and Latin America and $4 in other countries. Single copies: 30 cents.

Publication Office, Easton, Pa. Issued the middle of the month of publication.
Acceptance under Section 34.64, P. L. & R., authorized by United States Post Office.

Printed in U. S. A.

COMBUSTION

Editorials

We Have Just Begun to Dream

Our only living ex-President and a distinguished engineer, Herbert Hoover, used this title for a thoughtful and inspiring article which appeared in *The American Weekly* of last May 25. Mr. Hoover, in pointing to the commemoration of 100 years in the upward movement and accomplishment of the American engineering profession, recalled that forces resulting from freedom of mind, spirit and enterprise have brought our nation to its current point of industrial achievement. Noting that the centennial of the founding of The American Society of Civil Engineers reminds us of the glory in our productive past, Mr. Hoover added this view of of the future: "A possible vast field of scientific discovery and invention lies ahead of us."

COMBUSTION is devoted to the advancement of steam plant design and operation. What of the past and what of the future? Professor Theodore Baumeister of Columbia University, in a paper before the Convocation of the Centennial of Engineering in Chicago, noted that the thermal performance of steam power plants has improved from Edison's Pearl Street Station, with its equivalent heat rate of 150,000 Btu per kilowatt-hour in 1882, to a currently designed 200,000-kw boiler-turbine-generator unit having an anticipated heat rate of 9000 Btu per kilowatt-hour. At the same time the kilowatt capacity per employee increased from 90 in a 45,000-kw reciprocating-engine plant of 1903 to 2500 in a 1950 station having a capacity of 300,000 kw. Professor Baumeister calculated a theoretical limit set by the Carnot cycle with 2500 F combustion temperature of 4100 Btu per kilowatt-hour and for a nuclear energy power plant, assuming a fission temperature of 100,000 F, a heat rate just in excess of 3413 Btu per kilowatt-hour.

Engineering is constituted of both men and machines. That the machines of the future will be improved is certain, but what of the men? Rising over the horizon are some developments that were hastened by, if not a result of, demands for rapid technological improvements during World War II. The application of operations research and the development of complex computing devices in combination with automatic control systems are bound to have a profound effect upon future activities of engineers. How far can so-called "mechanical brains" take over routine repetitive calculations often now performed by engineers? And as more becomes known of the nature of human interaction that produces new designs and developments by co-operative teamwork, what is the probable effect on engineering manpower requirements?

To these questions there can be no assured answers at present. But dreams of the future must encompass more than 4100 Btu-per-kilowatt-hour steam plants and the harnessing of nuclear energy. They must also foresee frontiers which will vitally affect the mental sphere of the engineering profession.

Status of Nuclear Power

Members and certain key representatives of the U. S. Atomic Energy Commission have given numerous talks before scientific and engineering groups with reference to present and potential applications of nuclear energy and its by-products. As information becomes declassified, it is made available to industry, and as a further step toward a policy of keeping industry abreast of developments, other than information restricted for defense reasons, the Commission is offering a one-year course in reactor technology at a school it has established at Oak Ridge. It also suggests that promising young engineers and scientists be farmed out by industrial firms to the several laboratories engaged in developing special nuclear projects.

Despite the present uncertain economic aspects of atomic power, here is an excellent opportunity for some power companies, and even engineering firms, to augment their training programs to the end that they be prepared for what the future may offer.

To date the only case in which actual power production has been reported is that from an experimental breeder reactor that has been in operation since August 1951 at the Argonne National Laboratory. Here superheated steam is produced at 400 psi and, in turn, generates some 15 kw in excess of that required to operate the reactor. Detailed information on this has recently been declassified.

As is well known, several utilities and large chemical companies have been cooperating with the Commission for a year or more in making economic and engineering studies of nuclear power production. Concurrently, but independently from these studies, the Navy has gone ahead with the construction of two submarines to be propelled by nuclear energy while prototype land plants are being built. In fact, further studies are being made toward its application to a large carrier.

Some may question the wisdom of such steps before the practicability of nuclear power has been established on a smaller scale. Obviously, while the economics of the problem must be a guiding factor in any industrial applications, this is not so in the realm of defense. Had it been considered early by the Air Force, we would not today be so far advanced in jet propulsion. However, it is altogether possible that out of military experience may come useful information in stationary nuclear power production which at present seems somewhat distant.

Century of Engineering Progress Marked by Chicago Meeting

THE Century of Engineering, which held its Convocation in Chicago September 3–13 inclusive, involved more than sixty engineering societies which contributed to a program of approximately a thousand papers, reports and addresses. The idea underlying the meeting was to commemorate the founding, a hundred years ago, of the first national engineering society in the United States—The American Society of Civil Engineers. At that time civil engineering, as distinguished from military engineering, comprised all the branches now covered by various individual societies. It was also expected that the Convocation would serve to promote better public understanding of the engineering profession and its accomplishments.

The general program included sessions on a variety of industry topics and on subjects of widespread interest in which the engineer has an important role. In many of these the influence of power on industrial and social progress was predominant. A well-executed pageant termed "Adam to Atom" dramatized the historic American applications of inventions and engineering skills. The occasion also served for the presentation of the John Fritz Medal to Benjamin F. Fairless, president of the U. S. Steel Corporation, and the Hoover Medal to Clarence D. Howe, Canadian Minister of Defense Production.

Left to right: Lenox R. Lohr, director of the conference; C. D. Howe, Herbert Hoover and Benjamin Fairless.

Addressing the presentation luncheon, ex-President Hoover expressed the opinion that engineering and scientific progress in the next generation will depend upon an ability to keep out of wars and to get rid of unbearable taxation. "Such progress," he said, "will require individual freedom of mind, spirit and action." He added, "From Watt's invention of the steam engine down the long road of inventions to the latest electronic recorder, scientific discovery and engineering productivity have periodically saved the world from impoverishment by wars created through lost statesmanship."

Colonel Charlton S. Proctor, president of the American Society of Civil Engineers, in an address at the opening session, called for taking stock of equipment and facilities to meet the challenge that the engineer will face in the future. On the positive side he saw a record of proud

Left to right: Sir David Pye; R. J. S. Pigott, president of ASME; and Ing. Luis Giannattasio.

accomplishment; whereas on the negative side science is advancing beyond ability to regulate its power for destruction. While perfecting labor-saving devices and promoting means for raising living standards, engineers seem to have ignored their responsibilities for social impact, economic repercussions and the cultural implementation of their work. "The most desperate need today," said Colonel Proctor, "is a reconciliation of science, technology and engineering to reassure a world in fear of war and to re-establish man's confidence in the works of man. We are supporting an all-out material mobilization when the world needs first an all-out spiritual mobilization."

Concurrently with the general sessions of the Convocation, many of the participating societies held individual meetings at which papers were presented in their respective fields. These included, among many others, the ASCE, the ASME, the AIEE and the NDHA, from which the following abstracts of selected papers are taken.

At the International Presidents' Luncheon the guests of honor were Sir David Pye, president of the Institute of Mechanical Engineers, and Ing. Luis Giannattasio, president of the Pan American Federation of Engineering Societies (U.P.A.D.), Montevideo, Uruguay. O. W. Eshbach, president of the Western Society of Engineers, presided; Past President J. D. Cunningham welcomed the guests, who responded appropriately, and President Pigott of the ASME reviewed engineering accomplishments with a glimpse into the future under the title "What is Not Yet, May Be."

Future of Steam and Electric Power

Prof. Theodore Baumeister of Columbia University, in a general paper tracing the history of the stationary steam plant from the days of James Watt to the present, stated that the paramount position of steam power in the stationary field rests upon (1) its economy and (2) its reliability, both of which have shown remarkable development over the years. To produce one kilowatt-hour with a steam engine of the Watt era required the expenditure of between 150,000 and 200,000 Btu per hour in fuel energy. This is in contrast to the 9000 Btu per kwhr heat rate in single boiler-turbine-generator units of 200,000-kw capacity in a modern central station, a reduction of 95 per cent in fuel consumption over the intervening years.

Making certain assumptions for future load growth, the speaker estimated that by 1970 the annual electric utility generation in the United States would be on the order of 1000 billion kilowatt-hours, requiring an installed capacity of about 200 million kilowatts. Of this total power generation, 75 per cent is expected to originate in fuel, 80 per cent of which is estimated to be coal. Assuming an annual average plant heat rate of 10,000 Btu per kwhr in 1970 and an average coal heating value of 12,500 Btu per lb, the annual coal requirements of the utilities in that year would range between 200 and 300 million tons. This anticipated fuel consumption, in turn, will call for an average water supply requirement on the order of 200,000 cu ft per sec, or 400,000 cu ft per sec with a 50 per cent load factor. If this were potable water, it would be sufficient to sustain a population of billions of people. Even though alleviated by tidewater operations, reuse of water in flowing streams after sufficient evaporative cooling, and by the effect of cooling towers and spray ponds, the questions of water resources poses an important problem for the steam plant of the future.

District Heating

Over the signatures of seven past presidents of the National District Heating Association, a paper was presented by **A. R. Mumford** of the Research Department of Combustion Engineering-Superheater, Inc. dealing with the subject of district heating.

With reference to historical aspects it was pointed out that steam as a heating medium was first attempted in a crude way by Sir High Plat in England in 1653 and later applied by James Watt; but as an industry it dates back to the pioneer work of Birdsill Holly in this country in the early '80's. The New York Steam Company began supplying customers as early as 1882 and since its reorganization in 1921 its service has expanded rapidly.

Meanwhile central station heating sprang up in many other cities, a recent survey having shown 207 privately owned and 71 publicly owned district heating utilities in the United States and 12 in Canada. Of these, 17 also generate electricity. In all, 35 states and the District of Columbia are involved and geographical distribution appears to exert little, if any, influence. Convenience of use seems to be a greater factor than climate.

In most of these systems condensate is not returned, although in many cases the residual heat in the condensate is utilized for heating building-service water. The heat thus recovered amounts to 10 to 15 per cent of the total heat supplied. Automatic controls are advisable in order to conserve steam and fuel.

Advent of the steam turbine, with its high vacuum requirement, compared with the days of the steam engine, adversely affected the utilization of exhaust steam as a by-product for heating. Even though it was possible to bleed steam from turbines for this purpose, the necessity of locating electric utility generating plants near large bodies of water usually restricted the economic heating area for such a combination.

Although electric generating plants are no longer located so as to be near the electric load center, because availability of condensing water takes precedence, district steam plants are located in close proximity to both the steam and the electric loads. As existing low-pressure district steam plants approach obsolescence and fuel energy becomes more expensive it will be increasingly favorable economically to raise the pressure in the district heating plants and, using a turbine-generator as the pressure reducing valve, generate by-product electric energy. On the basis of tomorrow's loads such an operation can offer an important energy saving and even on today's loads can show a saving under sufficient base load. When the demand for chemicals becomes sufficient the combination carbonizing and by-product electric generation plant will be highly economical for district heating purposes.

In some cities central station steam is being supplied to groups of industrial plants involving relatively short distribution lines.

Looking to the future, with the district heating industry now soundly established, the opinion was expressed that it is in a position to attract skilled personnel who have excellent knowledge of fuel markets, equipment and operating technique as well as economic applications of the service.

Trends in Power Generation

In a paper entitled "Past Progress and Present Trends in the Art of Power Generation," **A. C. Monteith** and **A. A. Johnson** of the Westinghouse Electric Corp., speaking at an AIEE session, observed that the electric-utility power generating capacity of the United States, since the founding of the industry some seven decades ago, has followed the astonishing pattern of doubling every ten to twelve years. This rise in electrical energy capacity has come about through the growth of the country, expansion of industry, and the more extensive use of electricity for domestic purposes. The authors expressed the opinion that installed capacity would be doubled again within the next ten years and that there was no indication of saturation, looking a little further into the future.

An important development in the field of power generation has been the standardization of turbine-generators. The characteristics of steam turbine-generators lend themselves to standardization, but hydraulic turbine-generators probably will never be standardized because the conditions of nature dictate the hydraulic turbine and, consequently, generator requirements. Turbine-generators have been standardized for 11,500-kw, air-cooled and 15,000 through 90,000 kw for hydrogen cooling. While the acceptance of standardized turbines has

been good, orders for standard turbines compared to total turbine orders placed in the last two years, have shown a marked drop, because of changing conditions which should be recognized. First, the standards should be extended to cover even larger ratings as the trend is in that direction, and second, steam conditions adopted as standard for smaller sizes have not been kept abreast of current economic conditions. Serious consideration should be given to the adoption of reheat for ratings as small as 60,000 kw, as the trend for more advanced steam conditions with reheat certainly encompasses such ratings.

The weight per unit of rated output of turbine-generators has decreased over the years. This has been brought about as a result of the 3600-rpm unit, better design and use of materials and improved manufacturing techniques. Improved ventilation and new cooling methods, better metals, and attention to design details have made it possible to use less material per kva of rating. It is interesting to observe that by comparison with the 65,000-kw machines of 1943 (a condensing unit), a newly designed 200,000-kw unit will weigh 34 per cent less and occupy 30 per cent less space, on a kilowatt basis. Also of interest, the new single-shaft, 3600-rpm, 150,000-kw generating units will weigh one million pounds less than a 150,000-kw cross compound unit purchased five years ago and now running about two years. The advent of the analog computer as a design tool is a major contribution to the art of designing. Improved manufacturing processes and the use of frames fabricated by welding have been instrumental in reducing generator weight and volume. The reduction in generator weight per kva has benefits other than the better utilization of materials. It means that larger machines can be shipped fully assembled. Completely assembled turbine-generators up to 90,000 kw have been shipped ready for placing on the foundation in the power plant. This has many obvious economies and is a matter that will receive increasing attention.

In the face of rising production costs, and material and labor costs, the cost of power generation has been reduced. Increased loads, better load factors, careful attention to area margins between peak loads and installed generating capacity, technical advances, improved engineering techniques, larger and more efficient generators have all been helpful in producing the trend of decreasing electricity costs over the past years. Many utilities now are finding it necessary to seek increased rates to obtain a fair return on investment in the face of today's higher costs. Today fewer plant personnel are required per kilowatt capability of plant than were required in the past. In some areas of the country designers and users have turned to the outdoor power plant in an effort to reduce costs.

Progress in a-c generation has been outstanding, but ultimate goals have not been reached. A tremendous number of factors has contributed to advances in engineering, manufacturing, and application of generators for power systems. Better use of materials, increased knowledge of design and improved manufacturing techniques have resulted in lower costs and lower weight and volume of material per kva of rating. In turn, higher rated generators and power plants have resulted in more economic production of power. Waterwheel generators may be expected to deliver one-fourth to one-half more kilowatts without increasing size or weight. Turbine-generators will probably exceed 300,000 kw at 3600 rpm. The electric power industry has grown manyfold in its 70 years of existence. Today 80 million kilowatts, or 500 watts per capita, of capacity are installed. In the next ten years it is very likely that this figure will be doubled. Energy generated today amounts to about 2500 kw-hr per capita per year, and continues to grow at a rate of doubling in ten years.

Transmission Lines

In another AIEE paper entitled, "Progress and Future Trends in Electric Transmission," Messrs. **S. B. Cary** of General Electric Co., **I. W. Gross** of the American Gas & Elec. Serv. Corp. and **C. F. Wagner** of Westinghouse Electric Corp., offered the following principles of the economics of high-voltage transmission:

The cost per kilowatt of transmission line capability goes down with increasing voltage, whereas the cost per transformer kva for a given size increases with increasing voltage, and the cost per kva decreases with increasing transformer bank capacity rating. Accordingly, higher voltage becomes more economical when it is used to transmit a large block of power using large transformer banks at the step-up and step-down terminals. The higher voltage also becomes more favorable as the transmission line distance increases as the line investment becomes greater relative to the transformer investment. Today, with modern concepts of circuit loading, higher voltages can be justified at much shorter distances than was considered economical previously. For example, depending upon local conditions, it may be entirely practical with a voltage such as 330 kv to transmit 500,000 kilowatts, if required, a distance of 50 miles. For a double circuit tower this would be 1,000,000 kilowatts.

From the studies which have been made of higher voltage systems, a pattern of design has evolved which includes:

1. A system configuration such that the paralleled line may be kept equally loaded and relatively short by the use of high tension bussing at either end of the line and by the use of intermediate switching stations for the longer lines.
2. The use of step-up transformers directly from the generators to the high-voltage bus with possibly an autotransformer tied from the new high-voltage system to the existing lower voltage systems at the generator end of the high-voltage line as well as at the receiving end.
3. The use of large conductors of 800,000 circular mils of copper equivalent or greater.
4. Use of double circuit towers to reduce the cost of transmission, particularly where the right-of-way costs are high.
5. Use of quick reclosing circuit-breakers and quick relaying.

High voltage systems (230 kv and above) are expected to increase, particularly in the highly industrial areas where it is becoming increasingly difficult to obtain sites for generating stations near the load. Transmission distances of 50 to 100 miles from fuel-burning stations have become quite common in order to use favorable generat-

ing sites. Higher voltage transmission makes more attractive the use of large turbine-generator units and in this way also effects further economies. Transmission costs per kilowatt of capability for moderate distances at the higher voltage level are relatively low compared to generating station costs per kilowatt.

However, transmission of electrical energy even moderate distances is not competitive with pipeline transmission of energy by oil or gas the same distance. At the shorter distances oftentimes electrical transmission may be cheaper than coal by railway and therefore may fully justify a large generating station at the coal mine.

For distances from 200 miles to 600 miles, the series capacitor provides a means to realize an almost constant cost of transmission per kilowatt-hour per mile. It is expected that the higher voltages will continue to be studied and applied, particularly during this period of high rate of increase of kilowatt system capacity.

Burning Low-Quality Coal

A comprehensive paper on "Influence of Low-Quality Coal on Design and Operation of Pulverized-Fuel-Fired Units" was presented by **Otto de Lorenzi** of Combustion Engineering-Superheater, Inc., at the ASME Fuels Session. In this the author, after discussing certain fundamentals in furnace design with reference to outlet gas temperature and sintering when burning low-grade coal, proceeded to review superheat control with bypass dampers, desuperheating, multi-level burners, gas recirculation and tilting burners.

The first steps taken to combat difficulties due to the downward trend in coal quality was to reduce furnace heat liberation rates, completely water cool all wall areas and adopt wider spacing of tubes in the front boiler bank thus reducing entering gas velocity.

As to bypass dampers, the amount of gas that can reasonably be shunted around the superheater at full load is approximately 25 per cent of total flow, and the range for normal expected steam temperature is from about 75 per cent to 100 per cent rated load.

The capacity range over which desuperheaters are most effective will be determined by their location, as well as by the type employed. The preferred location of the direct-contact type, when the final steam temperature exceeds 850 F, is between the primary and secondary stages of the superheater.

Differential firing is where, as capacity decreases, an increasingly greater proportion of the fuel is burned in the upper furnace zone. Within this classification fall horizontal turbulent burners located at different levels which permit only the upper row to be in use at low load, yet maintain a reasonably high furnace outlet temperature. In the case of a number of large units employing this arrangement, in conjunction with bypass dampers, it has been found possible to maintain practically constant steam temperature down to 60 per cent capacity.

The two principal factors entering into superheater design and performance are inlet gas temperature and mass flow. By suitably changing their relation at a given capacity it is possible to obtain the same steam temperature. With gas recirculation, varying percentages of flue gas are withdrawn at some point between the boiler and air heater outlet and then reinjected into the furnace. If this gas is introduced at the entrance to the superheater, it will have little effect on performance as it serves only to increase the gas quantity and lower its temperature by dilution. However, if the recirculated gas is introduced so as to affect the heat absorption by the water walls, or the rate of combustion, it will have a decided effect on furnace and superheater performance. Application of gas recirculation will adversely affect performance, since both draft loss and exit gas temperature are increased. The magnitude will depend on the quantity and temperature of the gas, its point of reinjection, the power required for recirculation and the power increase for the induced-draft fan.

With tilting tangential firing, burner assemblies are installed in the four corners of the furnace, each assembly including a secondary-air compartment complete with fuel nozzles and air-guide vanes that may be tilted upward or downward as much as 30 deg from the horizontal and thus regulate the gas outlet temperature according to load. By this means furnace outlet temperature can be varied over a range of 250 F from full load down to below 40 per cent capacity.

The temperature regulation between horizontal and full downward tilt available at maximum design capacity may be used to compensate for any effect of sintered dust on the furnace walls.

In the case of reheat units the reheat steam temperature is controlled by burner tilt. As the primary superheater does not have the same temperature characteristics as the reheater, it is necessary to provide up to 2 or 3 per cent desuperheating spray water as supplementary control of the initial steam temperature.

In conclusion, the author stated that the wide range of steam temperature control obtainable with tilting burners is most satisfactory for the present; but if it should become desirable in the future to extend the range, it could be accomplished through adding gas recirculation to the tilting burner control.

Discussion

It was pointed out by one speaker that with poor coals or lower feedwater temperature supplementary control may be necessary. Another stressed the desirability of coal preparation; and a third called attention to the fallacy of operating with too high CO_2 because of a tendency toward excessive slagging, furnace exit gas temperature being a function of excess air. In one large midwest station the practice is to spray lime slurry over the radiant surfaces of the furnace, after cleaning, to prevent slag deposits. Here a saturated solution of soda ash is sprayed over the air heater to neutralize the sulfur in the fuel.

Boiler Controls for Multiple Fuels

Basic factors governing the design and selection of boiler control equipment for multiple-fuel firing were discussed in a paper by **A. C. Wenzel,** of Republic Flow Meters Company, who then proceeded to describe and illustrate control arrangements for nine specific fuels and combinations.

Selection of fuels is usually governed by local conditions of availability and economy, in which seasonal availability is often a factor. Where the boiler is de-

signed to burn either gas or oil separately, a relatively simple control system can be provided; but if conditions require simultaneous burning of both fuels and in various combinations over a wide load range, a rather elaborate control system with safety devices becomes necessary.

In arranging the fuel-burning equipment not only must the burners be selected to provide the desired load range, but the duct arrangement should be such as to permit accurate measurement of the combustion air. It is better to take a direct measurement of air flow before the air enters the burners or combustion chamber, or even before it enters the air heater, than to take an inferential measurement by determining draft loss. In fact, every effort should be made to measure the combustion air either at the inlet or the discharge of the forced-draft fan.

The nine specific combinations described by Mr. Wenzel were: (1) gas or oil burned separately; (2) gas and oil, with hand-set fuel-air rates; (3) two different gases with the fuel-air rates hand set; (4) two gases with automatic totalizing; (7) spreader stoker and oil; (8) two gases with steam-flow load control and pressure correction; and (9) gas and oil firing of a cyclone furnace.

Mr. Wenzel pointed out that there are many combinations other than those described and including such waste fuels as sawdust and refinery gases which must be burned to the limit of their availability and which present special problems with corrective devices and safety features. He added that the more complex problems can usually be handled with greater facility and simplicity by employing the electronic master control system with electronic splitters, totalizers and other computing devices. On the other hand, the simpler problems are more economically solved by use of pneumatic transmission and master-control devices.

Steel Works Power Plants

Waste or by-product fuels available in steel works constitute the principal reason for the existence of large power plants in that industry. In fact, there is sufficient potential heat energy in these waste fuels to generate all the power and steam requirements. Blast-furnace gas, as the principal by-product fuel, presents certain combustion and boiler design problems that are different from those encountered in burning the more common richer fuels.

The foregoing, as well as problems in meeting space limitations in six installations, were covered in a paper by **Robert W. Worley** and **Harold J. Bentson,** supervising engineers of United Engineers & Constructors, Inc. of Philadelphia in a paper before the ASME. The following reviews some of the high lights of their discussion.

The steel industry is the largest industrial user of electric power, one example being the Gary works which has an electrical load of nearly 200,000 kw. Such plants also require large quantities of steam for operation of blast-furnace turbo-blowers, mill engines, other steam-operated equipment, heating and certain process uses.

For every ton of coke produced there is about 8000 cu ft of coke-oven surplus gas with a heat value of about 550 Btu per cu ft and some 145 lb of coke breeze of 11,000 Btu per lb. This gas is used largely for metallurgical purposes, such as open-hearth and reheating furnaces.

The blast furnace is the largest producer of waste heat, in the gas issuing from its top. This represents from 9 to 14 million Btu per ton of iron produced. This blast-furnace gas, however, has a heat value of only about 90 Btu per cu ft. Some 25 to 30 per cent is used for preheating air going to the furnaces, some is used for underfiring coke ovens, and the remainder is available for making steam or for use in internal combustion engines, of which there are still a considerable number in use. It may eventually be employed for gas turbines.

If the surplus coke breeze is not sold it can be used for steam generation and will produce from 800 to 1200 lb of steam per net ton of iron. Considering the whole steam plant, there is sufficient heat theoretically available, and not otherwise used, to generate from 220 to 550 kw-hr per ton of iron produced in the blast furnaces.

The burning of blast-furnace gas, because of its low heat value, involves large boiler furnaces and relatively low combustion rates—not over 18,000 Btu per cu ft. Furthermore, since the gas when it leaves the top of the blast furnace is heavily loaded with dust, mostly iron oxide, dust catchers or wet scrubbers must be employed. Most modern installations use electrostatic precipitators, but even then there is apt to be trouble from ferrous slag accumulations on the boiler tubes unless the first-pass tubes are widely spaced.

Another difficulty encountered in burning blast-furnace gas is irregularity in its quality and burning characteristics, due to variations in the blast-furnace operation.

Power installations described in the paper included the United Steel Company's plants at Youngstown, Ohio, Gary, Ind., and Chicago, as well as the Republic Steel Corporation plants at Youngstown and Cleveland.

South Texas Outdoor Power Stations

A report on the operating and maintenance problems that have been encountered in three years of operation of two 60,000-kw Preferred Standard turbine-generators at the Greens Bayou Station and in two years of operation of two 60,000-kw handbook turbine-generators at the West Junction Station was presented by **Harry G. Hiebeler** of Houston Lighting & Power Company.

While the service record for 2300-volt conventional splashproof motors in outdoor service reflects several failures due to moisture, most of these can be attributed to inadequacy of design and the failure to acquaint the designer with extreme service conditions under which the motors may be called upon to operate. With the exception of difficulties at Greens Bayou occasioned by a severe storm the day after start-up, the motor performances of both plants have been excellent, particularly with the 440-volt motors rated up to 60 hp. For new outdoor stations the large motors will be of improved weatherproof design, incorporating air filters in air intakes.

Experience with outdoor plants has been too short to estimate the probable extra costs of maintenance painting over the indoor plant. All surfaces "weather" under the action of wind and rain, and to date nothing really satisfactory has been found for unlagged blowdown, vent piping and boiler breechings, even though it seems desirable from both appearance and economic viewpoints to lag such lines. To maintain turbine appearance, annual

spray painting is required, while boiler casings can go three to four years.

Mr. Hiebler observed that both operators and maintenance men in his company prefer working at the outdoor stations, and that it is believed that the open arrangement allows better supervision of power-plant operating activities.

Discussion

One discussor, speaking of experiences with a semi-outdoor plant near the North Atlantic Seaboard, mentioned some early troubles through low oil viscosity in winter having slowed down some of the controls.

Another, reporting on an outdoor plant in Mississippi where the temperature ranged from zero to 105 F, cited trouble through freezing of gages, blowdown connections, drains, etc. Also, on one occasion the shaft of the turbine had warped when shutdown due to cold air having rushed over the bottom. On the other hand, maintenance had been slowed down during the hottest days of summer. Although outdoor construction makes for considerable reduction in initial cost maintenance is increased through greater painting requirements.

Pressure Operation

Experience in pressure operation of large pulverized-coal-fired boilers at the Twin Branch, Philip Sporn and Tanners Creek plants of the American Gas and Electric System was detailed in a paper by **G. W. Bice**[1] and **W. M. Yeknik.**[2] This covers one unit of 150,000 kw capability at Twin Branch, four units of like capability at Philip Sporn and one at Tanners Creek. Two similar units are now under construction at Tanners Creek and three of 200,000 kw on order. Also the new Kanawha River and Muskingum River stations will each have three 200,000 kw units. All employ a single boiler per turbine.

The Twin Branch unit, which is also equipped with induced draft, was placed in commercial operation in August 1949 and had been expected to operate under pressure from the initial start-up. However, regular pressure operation was not in force for approximately two years, during which time frequent pressure runs were undertaken to study various difficulties encountered. From that time to the present the boiler has been operated under pressure for approximately 95 per cent of the total availability time for the unit.

At the Philip Sporn Station boiler No. 11 was first placed in operation in November 1949. In March 1950 several short-duration partial pressure runs were made with the forced-draft fans wide open and the induced-draft fans throttled to produce a furnace pressure of 11 in. of water at 120,000 kw output. During these runs severe gas leakage and rapid overheating of the retractable soot-blower wall boxes was experienced. Later, failure of the ash hopper water-seal skirt made it necessary to return to continuous suction operation.

After rectifying these difficulties, the boiler was again placed on pressure operation which is now normal, except for short periods of maintenance work on the mills, slag blowers and minor casing leaks or leaks around setting doors.

[1] Steam generation section head, American Gas and Electric Service Corp., New York.

[2] Manager of Twin Branch Generating Division, Indiana & Michigan Electric Co., Mishawaka, Ind.

Boiler No. 21 at the Philip Sporn Station went into service in June 1950 and followed the same general pattern as No. 11 in its transition from suction to pressure operation. The next two boilers, however, were sufficiently ahead of schedule to permit adequate pressure testing prior to initial operation and were operated on pressure almost from the initial start-up. They both have high-speed forced-draft fans which it was found could be throttled sufficiently to permit low-volume air flow during starting.

One difficulty, common to all the Sporn units, concerned the removal of relatively large chunks of slag from the ash pits and it became necessary to transfer to suction operation and lance through large access doors.

The first unit at Tanners Creek went into service in March 1951 and the two other 150,000-kw units are under construction. Initial plans included provision for future induced-draft fan bypass dampers, with blanking plates to be installed initially. However, experience at Twin Branch was considered sufficient to warrant installation of the bypass dampers. After the first few hours of pressure operation, leaks in the hopper-slope casing made it necessary to return to suction operation for several weeks. With these leaks corrected, pressure operation was resumed for about 75 per cent of the time but difficulties developed at the lower section of the convection pass rear wall and suction operation again had to be resumed for a while. During the spring and early summer of 1952 pressure operation has been normal from 95 to 99 per cent of the time.

The paper enumerated the advantages and disadvantages of pressure operation as follows:

Advantages under Both Pressure and Suction Operation

1. Due to reduced setting leakage, operation with lower excess air is possible with accompanying improvement in boiler efficiency.
2. Improved superheat and reheat control characteristics, compared with boilers having conventional casings.
3. Better control of furnace conditions due to absence of variable setting leakage.
4. Smaller flue gas outlet equipment as a result of less gas to be handled.

Advantages under Pressure Operation

1. Reduced auxiliary power.
2. Reduced auxiliary heat loss, since all the heat loss due to draft fan turbulence is added to the air ahead of the air heaters where approximately 40 per cent is recovered.
3. Reduced fan maintenance.
4. Improved air-flow control.
5. Safer operation during starting up and low-load.

Advantages with Unit Designed for Pressure Operation Only

1. Reduced boiler plant investment which results from elimination of material and installation labor for induced-draft fans and associated equipment.
2. Basic simplification of automatic control system since no provision need be made for furnace-draft regulation or forced-draft fan trip interlocking.

Disadvantages of Pressure Operation

1. Increased cost of casing, seals and aspirating air piping as well as leak-proof construction of ash hoppers, soot and slag blowers, dampers, automatic oil lighters, primary fans, etc.
2. Limited access.
3. Difficulty in locating tube leaks.
4. Difficulty with soot and slag blowers as the required close clearance of air-sealed wall boxes are more likely to cause binding under slight misalignment due to warpage.
5. Difficulty with rotating shaft seals, although these have now been improved.
6. Difficulty with ash and slag removal.
7. Increased coal bunker fire hazard when burning high-volatile coals.
8. Possible dust nuisance through minor casing leaks during early months of operation.

Conclusions

Comparisons of performance under pressure and suction operation at all three plants show improvements in heat-rate ranging from 55 to 93 Btu per net kwhr with pressure operation.

The authors conclude that for large pulverized coal-fired boilers pressure operation is practical provided several short-duration shutdowns to correct leaks can be tolerated in the early months of operation; and that air-pressure testing of the entire setting prior to initial start-up is essential. The significant difficulties remaining involve pulverizer maintenance, raw coal feeder clearing, slag-blower sealing and bunker fire protection with high-voltatile coals. They suggest that when heavy slagging or ash-removal difficulties are anticipated the boilers be equipped with standby induced-draft equipment.

Discussion

One discusser emphasized the necessity of preliminary testing before such a unit is placed in service, in order to make sure of the tightness. For large units he recommended from ten to fifteen 8-hr shifts. Seven oil- and gas-fired units have thus far been installed without induced-draft fans, and four cyclone-furnace units have been so installed. A wide-range lancing door, developed by B & W will soon be field tested.

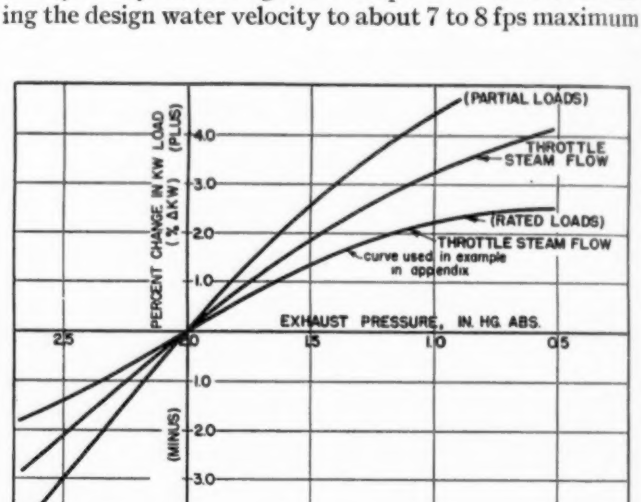
Another called attention to the extra investment and the fact that fuel system repairs will cost more; also that the added plant labor cost must be balanced against reduced induced-draft fan maintenance and power saving.

In answer to question one author stated that the necessary seals do not cost as much as the induced-draft fan; that it is possible to operate with 10 per cent excess air, with no CO and without smoke; and that a tube rupture with pressure combustion usually means shutting down the unit.

Surface-Condenser Design

"Optimum Design for Surface Condensers" was the title of an ASME paper by **James T. Fong,** mechanical engineer of Burns and Roe, Inc. In selecting surface condensers for steam power plants, the consulting engineers have to specify to the manufacturers most of the design variables governing the sizing of the condenser. Often the choosing of the design variables is based on the engineers' experience or dictated by physical, metallurgical and structural requirements, but it is possible to derive mathematical relationships between the variables so that the total annual fixed charges and the total cost chargeable to the circulating water system including pumping charges is at a minimum.

It is found that in most cases, with the unit costs proposed, the value of the optimum circulating water design velocity is somewhat higher than that specified in the industry today indicating that the present trend of limiting the design water velocity to about 7 to 8 fps maximum



Correction factor for turbine output or heat rate due to variation in back pressure

is primarily due to considerations of tube erosion. By means of mathematical analysis the author was able to show a decreasing value of optimum water velocity as the tube length of the condenser decreases. He also derived a general equation and developed a graphical solution for the optimum tube length of the condenser. Emphasis was laid on the proper choosing of circulating water inlet temperature and condenser vacuum as the design value.

The performance of any condenser may be represented by a general equation so that its effect on turbine exhaust pressure at different loads may be evaluated in terms of decreasing or increasing plant output. All these considerations enter into the optimization of surface condensers for steam power plants.

Demineralizing Experience

Supplementing previous reports[1] on the 1250-gpm demineralizing equipment at the Schuylkill Station of the Philadelphia Electric Co., **V. B. Burgess** and **D. N. Purcell** of that organization gave an account of the operation and performance of this installation for a period of 18 months following start-up. While the equipment has consistently produced water containing less than 2 ppm mineral solids and 0.02 ppm silica, some falling off in the capacity of the cation units (without loss of

[1] See COMBUSTION, May 1951, pp. 32–33.

quality) was experienced after approximately six months operation.

Laboratory observations indicated that the cause of poor water quality and capacity drop following cation regeneration was the presence of large congealed clumps of resin. During the backwash period these lumps could not be broken up, with resulting poor quality water and short runs. It was decided that more agitation of the surface resin was required to remove the fouling material that was accumulating on the resin, and a subsurface washer was installed in one of the cation units at Schuylkill Station. This resulted in a marked improvement which brought the exchange capacity above the guarantee value.

Some changes have also been reported in boiler water characteristics since the installation of demineralizers. Previously the water had been crystal clear, which then changed to a straw color as a result of an organic build-up of between 80 and 100 ppm, the source of which was found to be organic material in city water used for make-up.

After two months operation an internal inspection of the boiler showed that there was a soft gray-brown deposit throughout the boiler but most prevalent in the feedwater inlet drum and the downcomer tubes from this drum. Chemical analysis of the deposit indicated that calcium phosphate, possibly as the hydroxy apatite, and iron oxide were the main constituents. After several trials it was decided to employ an organic dispersing agent at low dosages, and this showed a less rapid build-up of boiler deposits. Currently a residual of 75 ppm of organic is being maintained in the boiler water by batch treatment. Latest inspections show a considerable reduction of deposits on boiler surfaces.

Nuclear Energy Applications

In a paper entitled "Industrial Applications of Nuclear Energy," **Alfonso Tammaro,** manager of the Chicago Operations Office of the Atomic Energy Commission told of some of the research and development phases of A.E.C. field operations and gave further information on the Experimental Breeding Reactor at Argonne National Laboratory.

The EBR, as it is known, generated the world's first significant amount of electricity from a nuclear reactor heat source on December 20, 1951, when four bulbs were lighted. The following day, the external electric supply to the building was discontinued, and the entire power load was carried by the reactor-boiler-turbine-generator system. This included all electrical lighting, power for the reactor auxiliaries, and power for a machine shop.

Heat energy is removed from the reactor by a liquid sodium potassium alloy leaving the system at 625 F, which then generates superheated steam at 400 psi. The reactor power load is approximately 85 kw, and excess amounts not required from the 100-kw generator are used for building service or dissipated to the atmosphere by electrical heaters. The power density is 250 kw per liter, and the neutron flux is approximately 10^{14} neutrons per sq cm per second. The reactor core (the section containing the fuel) is approximately the size of a regulation football. Electromagnetic pumps and flow meters are used in the liquid metal circuits.

A Letter to the Editor

This is one letter to you which you will not see until it appears in print in the columns of the magazine you have edited with distinction for nearly two decades. Its purpose is to congratulate you on the recognition you received at the meeting of the Metropolitan Section of The American Society of Mechanical Engineers on October 6th last in being made a Fellow of the Society. It was certainly a well deserved recognition not only of the constructive work you have done for the ASME through the years but also of your high professional achievement in the field of engineering journalism.

In expressing these congratulations to you on behalf of your associates on COMBUSTION, I believe I am speaking also for your host of friends and well wishers within the Society and among the readers of this magazine.

I have asked the printer to append to this letter a copy of the citation you received at the October 6th meeting and a photograph taken on that occasion.

CHARLES McDONOUGH, *Vice President*
Combustion Publishing Company, Inc.

A. D. Blake, George Sokolsky, noted columnist and speaker for the occasion, F. L. Bradley, chairman of ASME Metropolitan Section, H. R. Kessler, ASME Vice President

Citation

Alfred D. Blake is a graduate of Cornell University with an M.E. degree. He began his engineering career with Westinghouse, Church, Kerr, consulting engineers, was associate editor of "Power" and served in the United States Army during World War I with the rank of Major. After the war he returned to "Power" where he rose to managing editor. Later he served briefly as editor of "Steam Plant Engineering." In 1933 he joined Combustion Publishing Company and has been editor of COMBUSTION since that time.

Mr. Blake has guided the editorial policy of COMBUSTION so well that power engineers regard that publication as one of the outstanding technical journals in the world. Its articles have been authoritative and have made major contributions to technical development.

Kyrene Steam Plant Designed for Southwest Conditions

This article, based on a paper presented at the AIEE Pacific General Meeting held in Phoenix on August 19–22, describes a recently completed 30,000-kw outdoor steam plant designed by the Bechtel Corporation for the Salt River Power District. Economy studies which led to the decision to employ this type of construction are cited, along with features of a centralized control system requiring a minimum number of operators. A 350,000-lb-per-hr bent-tube steam generating unit serves a 30,000-kw Preferred Standard turbine-generator having throttle conditions of 850 psig, 900 F.

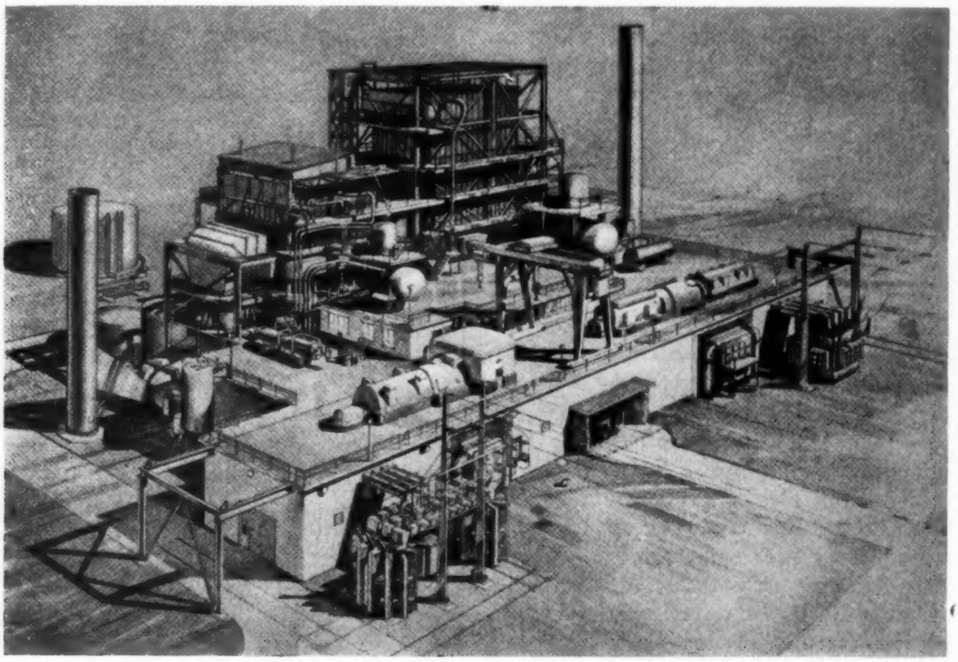
By T. M. MORONG,*
I. R. CARACO† and
E. J. LAUERMAN*

THE Kyrene Steam Plant is located 12 mi southeast of Phoenix, Arizona, in the Salt River Valley where the climate is mild in the winter and hot in the summer. The valley precipitation is less than 8 in. of rain a year and the sun shines an average of 85 per cent of the possible time. A climate with such favorable factors is conducive to an outdoor steam plant, although some of these favorable factors are over-compensated from the personnel comfort standpoint with daily temperatures of 100 F, or higher, commonplace during the summer months. On an occasional day or two in winter, the temperature drops below freezing in the early morning hours. This requires protection for operating and maintenance personnel. In addition, air and water lines must be protected from freezing.

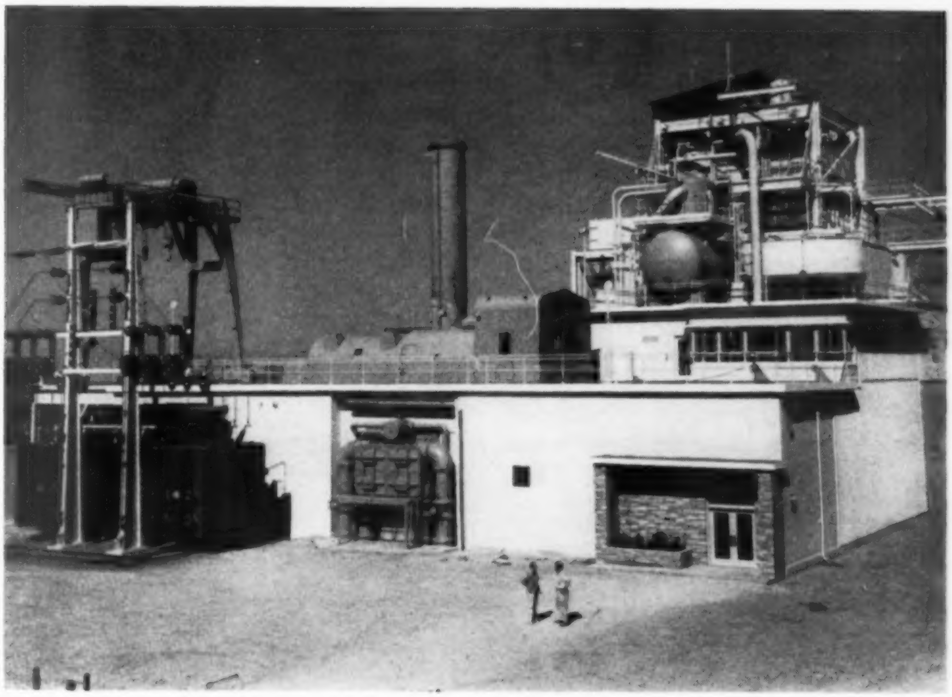
Although precipitation is light over the year, storms are not infrequent in January and February, as well as July and August. Many storms are accompanied by considerable dust and oftentimes no rain. Then again, cloudbursts can occur, although infrequently, in any section of the valley, causing considerable local damage and flooding.

After weighing the above favorable and unfavorable local weather conditions, the District and the contractor were convinced that attractive savings in first cost could be gained with an outdoor design. The Project has had considerable operating experience with outdoor distribution substations and pumping plants. This experience combined with previous designs by the contractor and the knowledge gained from inspection trips to outdoor power plants, was utilized in making the final design

* Salt River Power District.
† Bechtel Corporation.



Architect's sketch of Kyrene plant



Front view of plant showing simple entrance and control room on turbine deck. Firing aisle is at this level.

arrangement. The extent to which various components of the plant could be exposed to the elements was determined by balancing the first, operating and maintenance costs as they were affected by the local weather conditions.

Plant Design Features

Although the final design did not result in an all-outdoor plant, the major components and most of the larger auxiliary equipment are exposed to the elements. The remaining auxiliaries are located below the turbine deck and are enclosed by a lightweight pumice block curtain wall. The enclosed area is pressurized by means of a blower operating in conjunction with an air washer and exhaust fans are placed around the enclosure walls.

A weatherproof cover over the turbine and walk-in housing over the turbine standard were the only extras necessary to accomplish the outdoor move of the turbine-generator. A walk-in housing will not be included on the second unit. A shed-roof was added over the boiler firing aisle adjoining the control room and will be extended over the boiler firing aisle of Unit No. 2 The arrangement of turbine and two-pass condenser allowed the exposure of one condenser water box and circulating piping and valving for that end.

The evaporator and air-ejector are also located outdoors on the main operating or turbine deck. The deaerator and boiler feed storage tank are located on the roof of the office and control room, one level above the turbine deck. The hot-process lime-soda softener, reactor tank and effluent filters are located adjacent to the plant enclosure. All auxiliary transformers are located outside at ground level.

Cost Versus Weather Conditions

Each of the foregoing equipment items and plant design features was adopted only after it was determined that lowest ultimate cost per kilowatt would result. A review of the analysis for these design features follows.

It is estimated seven dollars net per kilowatt were saved by elimination of full height walls, a roof, heavy building steel to support the roof and crane, high bay lighting, ventilation equipment and foundation footings. The gross savings were partially offset by the weatherproof cover over the turbine, the walk-in housing over the turbine standard and the shed-roof over the firing aisle. It is difficult to discover any additional operating costs by the location of this equipment outdoors. Maintenance costs will probably be higher as temporary protection against the weather may have to be provided during major overhauls of the unit.

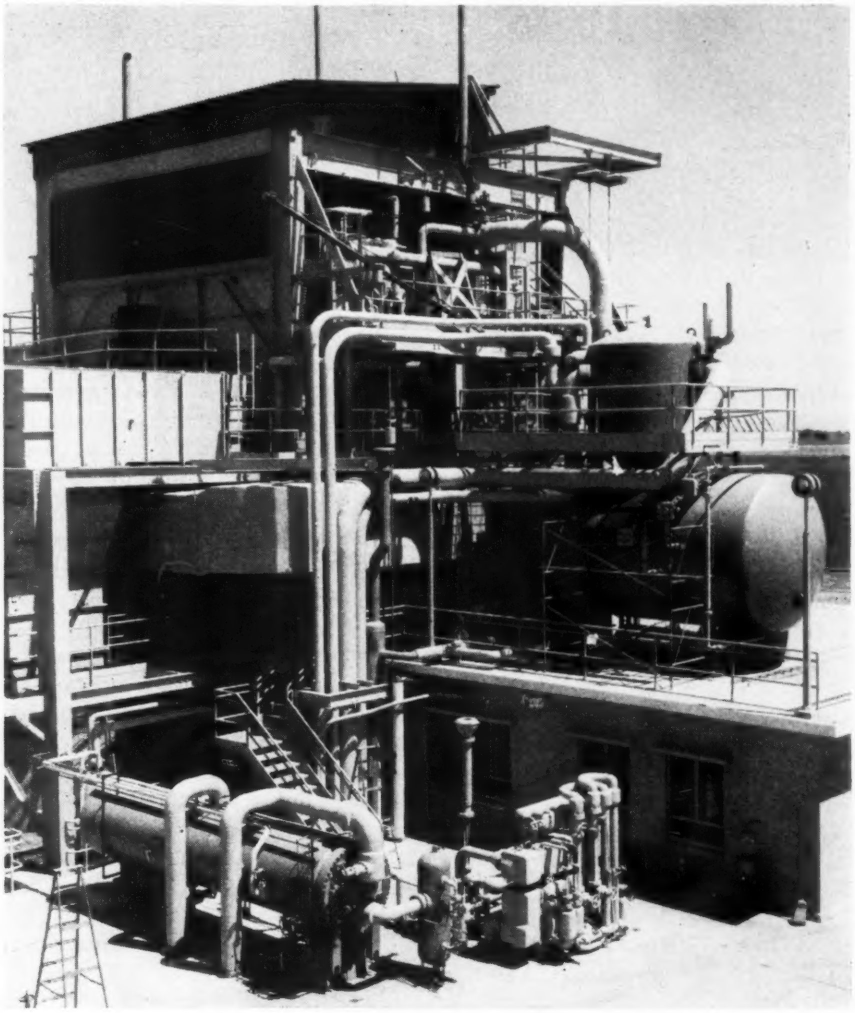
The evaporator, air ejector, deaerator and boiler-feed storage tank all partially share in the cost savings previously ascribed to the elimination of plant roof, superstructure, etc. In addition, their location outdoors materially contributed to the reduction of space required to be enclosed. The evaporator and air ejector relocation help to reduce space requirements below the turbine deck. These steam auxiliaries require no additional protection against weather for outdoor operation and normally require little operator attention or maintenance wherever their location.

Very little savings were indicated in first cost by exposing the auxiliary equipment to the elements. To adequately protect the auxiliary equipment without an outside enclosure, would require expensive enclosed motor drives and weatherproofing of other miscellaneous parts.

Enclosing the auxiliary area offers attractive advantages such as reduced operating, maintenance and outage costs. An operator or maintenance man could hardly be expected, in an exposed plant, to make adequate operating inspections or perform maintenance under adverse conditions such as dust storms or downpours. Under such conditions, foreign materials or moisture entering the equipment could seriously damage the equipment or shorten its life. However, this might be avoided by expensive duplication of equipment. Inability to ade-

quately operate and maintain under adverse weather conditions could result in reducing plant reliability and increase outage during such periods. Future outages might be a direct result of contamination picked up while making repairs during adverse weather.

The enclosure eliminates the need for longer runs of air and water lines and expensive covering of these lines to protect them against freezing temperatures. Pressurizing the enclosure and washing the air prevents the intrusion of dust and other foreign matter. Although this equipment increases the first cost, it is believed that the savings in maintenance expense and operator comfort more than compensate for this.



View of boiler showing shed over firing aisle; evaporator and air ejector in foreground.

The inherent design of the major equipment makes it impossible to utilize every cubic foot in the space bounded by the plant for equipment purposes. Advantage was taken of this by locating the machine shop, instrument repair room, laboratory, reception room, chemical treatment, storage room, and locker room inside the enclosure below the turbine deck. Very minor increases in overall dimensions were required because of this. The construction of an administration and service building located separately from the plant was avoided by the incorporation of these rooms into the plant enclosure. All of the inexpensive pumice block enclosures, including those below the turbine deck, control room and station office, are estimated to cost far less than the equivalent space if placed in a separate building for the purposes intended.

It is the opinion of the authors that limitation of the outdoor features as incorporated in Kyrene results in the lowest overall ultimate cost. Reduced maintenance, operating and outage costs far outweigh any minor differences, if any, resulting from the addition of the auxiliary area enclosure.

Operational Features

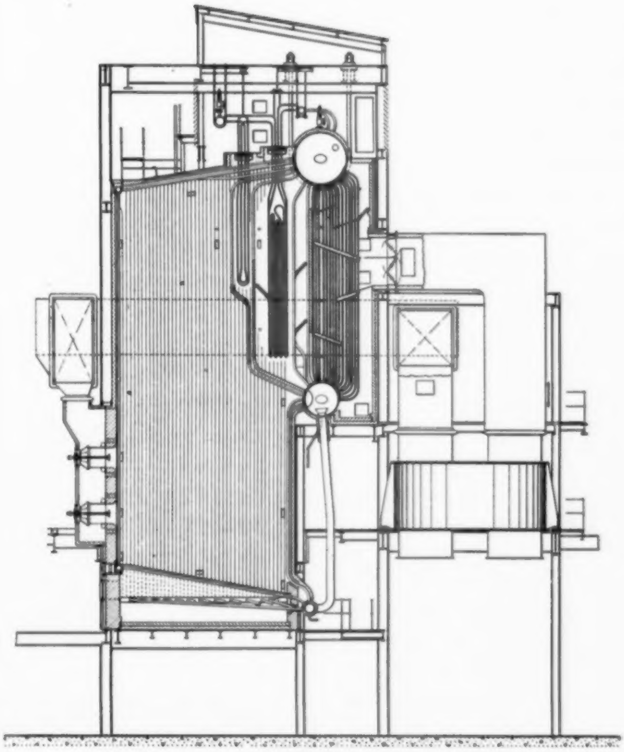
An outstanding feature is the small number of operators—a total of three per shift for the present unit. This amounts to a substantial saving in operating costs, which is made possible by the extremely compact arrangement and the numerous automatic design features which include centralized control, automatic feedwater and combustion control and highly automatic electrically-driven station auxiliaries.

The auxiliary equipment on the levels below the turbine deck has been arranged compactly, yet conveniently accessible to the auxiliary tender normally stationed on the ground level. Adequate stairways are provided to the 10-ft level where most of the manual controls and valves are located. These are easily reached from the adjoining grated steel walkways in times of control malfunctioning or plant upset conditions.

Controls, automatic and remote manual, for all of the primary elements of the plant are centralized in the main control room located on the operating deck. The control-room operator is stationed here and the shift foreman, as roving operator, operates from this point as his headquarters. This room, the nerve center of this central station, has a modern luminous plastic ceiling and is air-conditioned for the summer months and electrically heated in winter. It is totally enclosed except for windows in the double doors and one small window provided to view the boiler drum water level via mirrors.

On the turbine and mechanical console board which is set out in front of the vertical gage board, the main mechanical systems are depicted in mimic in color-coded brass symbols. Complete with miniature instruments automatic control selectors and electrical control switches, this picture board shows the flow of steam, condensate, feedwater, fuel, exhaust gases and control air. The arrangements of the controls are such that one operator can load the turbine and change load without leaving his initial position. Boiler-drum level is also visual to him at this same location.

The electrical control board is a conventional bench board with control switches on the console and instru-



Section through C-E two-drum boiler

ments on this vertical section. A color-coded mimic bus duplicates the switchyard and main electrical single line system on the console. The relay board is located in the cable spreading room directly below the control room, minimizing the bench board size and making for a more compact control room. All lock-out auxiliary relays and their cut-outs are located on the electrical control bench board.

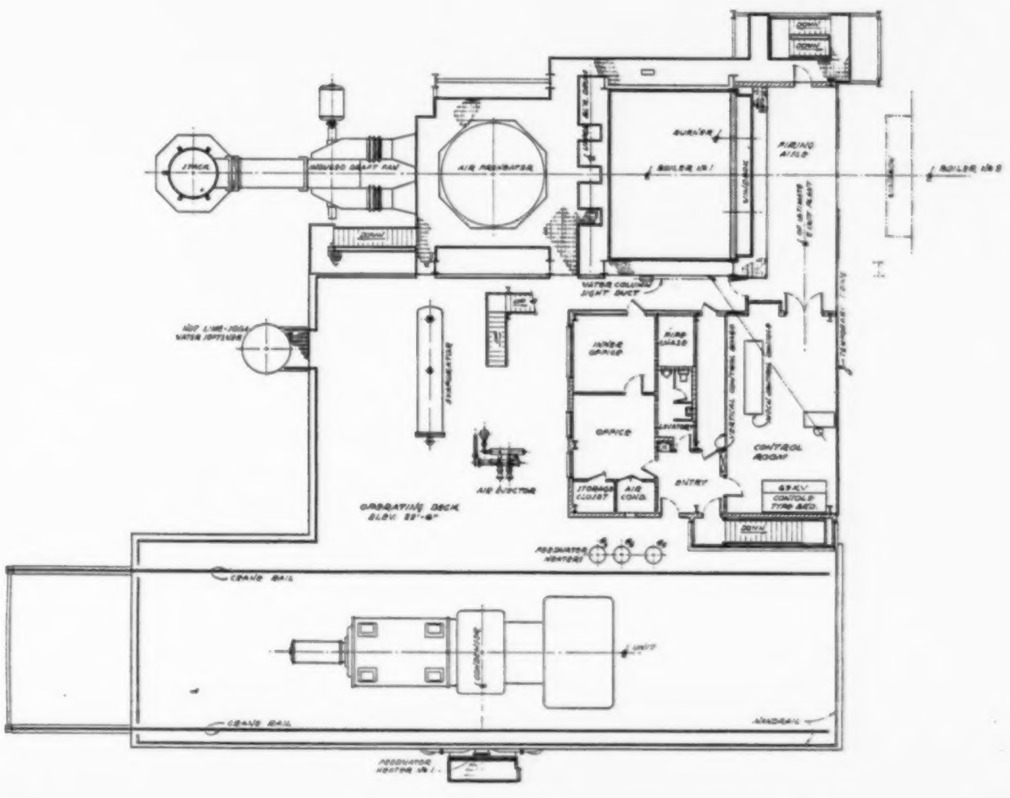
On the electrical board and the vertical gage board are located the annunciators with their red, green and white windows. These operate in conjunction with the alarms to aid the control room operator in supervising plant operation with a minimum amount of time consumed on detail. Each color represents the relative importance of the condition indicated. Several annunciators, which specifically require the auxiliary tender's attention, are duplicated on an auxiliary mechanical annunciator panel on the ground floor. Phone stations on a common-talk selective or code call dial phone system, are strategically located throughout the plant and adjacent structures.

General Description

The Kyrene site was chosen from a study made of four possible locations in the Salt River Valley. It was determined the most economical after an evaluation based on the major factors of condenser cooling water, fuel supply, accessibility to railroad, power wheeling and increased breaker interrupting capacity. The plant site abuts on the Western Canal, a major canal splitting into three minor canals flowing to the west from the site. The Western Canal stops flowing a few days in the year and this occurs simultaneously with low load demand, thus minimizing cooling tower capacity and operation. The major structures on the plant site include the main outdoor plant, cooling water intake and discharge structures, cooling tower, fuel oil tanks and 69-kv switchyard.

Steam Generating Unit

The steam generator is designed to produce 350,000 lb of steam per hour continuously, with a maximum capability output of 375,000 lb per hr for a four-hour peak, at 925 psig and 905 F total temperature. It has a

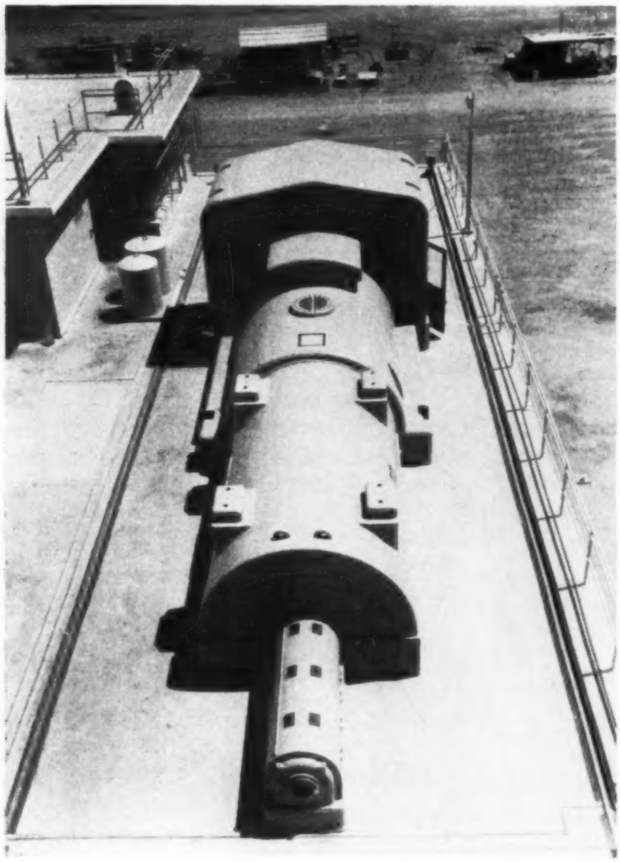


General layout of the plant for the first unit. A machine shop is located below the turbine deck.

water-cooled furnace; a two-drum bent-tube boiler with a two-element superheater; a regenerative air preheater; combination fuel burners which will operate with either oil or gas; and automatic combustion, feedwater and superheat control. A constant-speed motor-driven forced-draft fan supplies air to the burners and a constant-speed motor-driven induced-draft fan with louvers delivers the flue gases to the self-supporting steel stack. Both fans are located at ground level. The plant is designed for burning natural gas automatically, or fuel oil manually and can be converted to burn coal or lignite if economy should so dictate.

Turbine-Generator Unit

The turbine-generator is an AIEE-ASME Preferred Standard unit with a nameplate capacity of 30,000/33,000 kw and nominal throttle conditions of 850 psig and 900 F. With the throttle pressure increased five per cent and the liberal design tolerances used, a continuous capacity of 37,000 kw is obtained. The only valve in the main steam line between the superheater outlet and the turbine valve chest is the hydraulically operated stop valve supplied by the turbine manufacturer. The unit is designed for outdoor operation with a walk-in housing over the head end of the turbine.



The turbine-generator is of G. E. outdoor design

Gantry crane service of 30 tons capacity is provided along the turbine deck for installation and overhaul of the main unit with a 10-ton auxiliary hook arranged for convenience in handling lifts outboard of the crane runway and turbine foundation.

The generator is a hydrogen-cooled 12.5-kv, 3-phase, 60-cycle, 35,294/40,588-kva machine connected directly to the main and auxiliary transformer by isolated phase bus through flexible joints provided for earthquake protection. The main transformer ties into the 69-kv switchyard generator position 500 ft to the west by aerial conductors. The switchyard is a major tie point on the system. There is a direct-connected 250-volt exciter and a separately driven amplidyne voltage regulator. Provision has been made for the future use of a spare exciter, although none is contemplated when the second unit is added.

Condenser and Feedwater Cycle

The turbine exhausts to a 27,500-sq ft two-pass condenser with vertically divided water box and having a normal circulating water flow of 25,800 gpm. For the short period each year when there will be a deficiency of cooling water in the Kyrene Canal, the water will be recirculated over the two-thirds capacity cooling tower. Condensate from the condenser is handled by two full-capacity motor-driven condensate pumps discharging through the air ejector and first stage of regenerative feed heating to the deaerating feedwater heater.

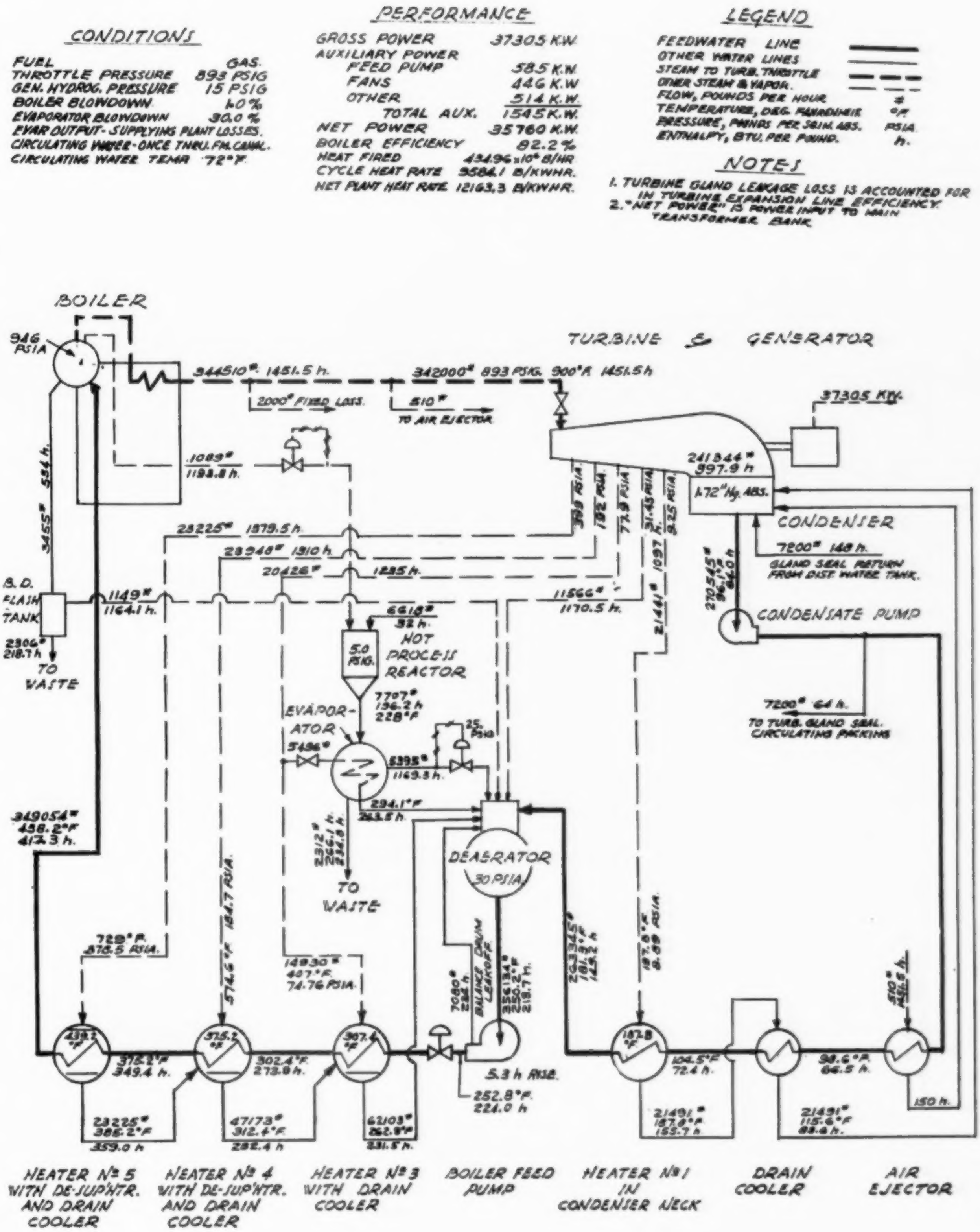
Two full-capacity motor-driven double-case main feed pumps take their suction from the deaerating heater storage section and discharge through three high-pressure heaters to the boiler. Steam for the feedwater heaters is extracted from five turbine bleed points and heats the feedwater to a final temperature of 438 F at 37,000-kw load. Drains from the highest pressure heater are cascaded from one heater to the next, and finally to the deaerator. Drains from the low-pressure heater in the condenser neck will be cascaded to the main condenser. Makeup feedwater is obtained by evaporating treated water in a 15,000-lb-per-hr evaporator incorporated in the feedwater heating cycle, the evaporated vapor makeup going directly to the deaerator as steam.

The high-pressure closed heaters are of the vertical type with the channel at the bottom. This type of construction allows the water nozzles to be welded and tube maintenance to be accomplished in place after removing the shell with the auxiliary crane hook through a hatch in the operating deck. The deaerating heater is of the vertical spray type with a total of ten minutes water storage at full load. The normal steam supply for this heater is from the fourth extraction point with provision for automatic supply from the third extraction point when the heater pressure decreases to 4 psig and for the admission of live steam from the auxiliary steam system when the pressure falls below 2 psig. Thus, effective deaeration is obtained over the full load range of the plant.

Piping has been designed to make the maximum use of welded construction. In general, flanged joints are provided only where necessary. Motor-operated valves are fitted where desirable for convenience and control. All valves are readily accessible for manual operation and most are located at the 10-ft level and adjoining steel grated walkways.

Controls

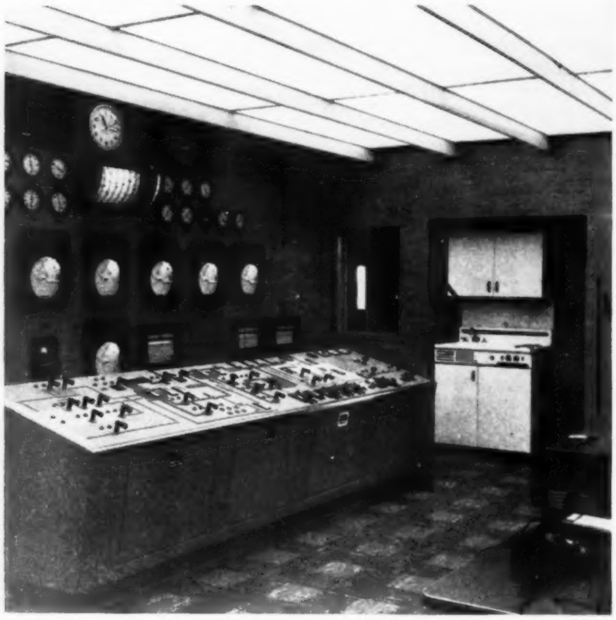
The 69-kv electrical and the mechanical control boards are located in the control room at the turbine-generator level. The mechanical controls and instruments are centralized in the control room on a schematic picture-



Flow diagram and essential data

type console board using miniature instruments. Recording meters and indicating gages are mounted on a vertical panel directly behind the console. Pressure control relays are placed behind the vertical board on the wall with convenient access to all tubing. The mechanical boards are so arranged that one operator can bring the turbine up to load and change load without leaving his initial position. In addition, he is only 20 to 25 ft from the burner front.

The control room is air conditioned and heated electrically. In addition, it has sound-proofed walls, luminescent-lighted anti-glare ceiling, asphaltic-tile floors, no windows except to the firing aisle, and pullman kitchen making for the maximum operator comfort and efficiency. The station chief's office adjoins the control room and is also air conditioned and sound-proofed. Two doors exiting to the control room and firing aisle place him within a few steps of the critical control points in emergencies. Also to assure that a minimum of the operator's time and attention is consumed in detail, an extensive annunciator and alarm equipment has been installed to constantly supervise all electrical and mechanical equipment.



The control room is arranged for convenient operation.

Makeup and draw-off of distilled water from storage tanks are determined by the deaerator water level which is maintained between limits by level controllers. Automatic level control valves for steam drips from closed feedwater heaters and many other automatic controllers reduce the operation personnel to a minimum.

The 2300-volt boiler-feed pump and draft-fan motors are connected directly to the 3-mva station auxiliary bank. A standby 6-mva bank sufficient for both units No. 1 and No. 2 has been installed initially, and an automatic transfer provided in case of failure of the normal auxiliary supply. The remaining auxiliary motors are served from the 480-volt system consisting of a 1000-kva air-cooled transformer feeding a metal enclosed 480-volt air-circuit-breaker board and in turn a 480-volt cabnetrol switchgear assembly.

Units for Joppa

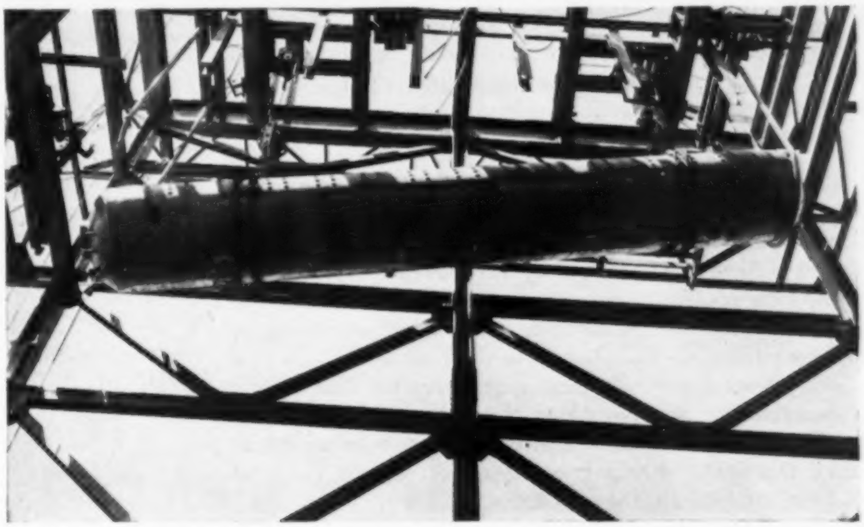
EARLY in 1951 it was reported in these columns that the U. S. Atomic Energy Commission had projected a new installation on the site of the former Kentucky Ordnance Plant near Paducah, Ky. To supply the vast amount of power that would be required, the Commission arranged with the Tennessee Valley Authority to build a large new steam plant to meet approximately half the demand, and for the other half it negotiated further with a group of five privately owned electric utilities to form a syndicate designated as Electric Energy Inc., to construct and operate a huge steam plant across the river at Joppa, Ill. This plant was designed to contain initially four 216,000-kva turbine-generators each served by a single steam generating unit of the reheat type operating at 1952 psig, 1055 F total steam temperature. Since then two more boilers have been ordered.

Construction of the plant is now well under way and shipment of boiler components and the first of the turbine-generators has been made. The accompanying photographs show one of the steam drums being raised into position, and another on a special car ready for shipment. These drums have a total length of nearly 50 ft, an outside diameter of 70 in. and are of welded 6 $^{3}/_{32}$ in. plate. They weigh 240,000 lb each. Design pressure is 2150 psig. The boilers are designed to burn Southern Illinois coal, natural gas or oil, tangentially fired with vertically adjustable burners.

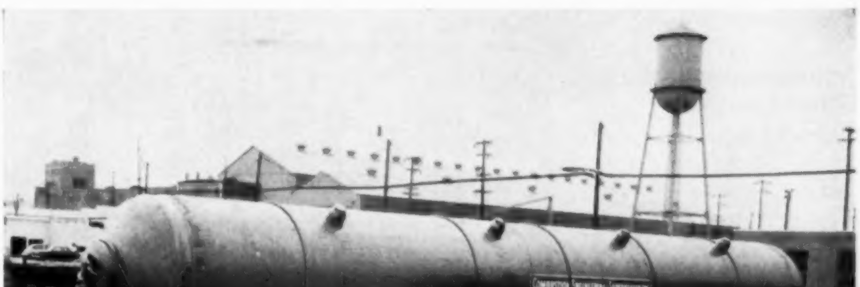
Each of the turbine-generators will be nearly 82 ft long, 17 ft wide and extend more than 10 ft above the floor level. Because of shipping limitations, the generator stators are subdivided into inner and outer frames, the former containing the core and coils and the latter split into three sections which are shipped separately and bolted together at the destination. The turbine-generators are of the outdoor type and the largest 3600-rpm machines yet built.

The steam generating units are being supplied by Combustion Engineering-Superheater, Inc., and four turbine-generators by General Electric Company. Ebasco Services designed the plant and is supervising its construction.

Welders shown joining ribs and sides of a section of stator



Drum being raised into position at plant



Drum on special car ready for shipment

Development of Improvements in Boiler Water Level Gages

By FRANK PTACEK

Mechanical Engineer

Yarnall-Waring Company

TOO often a boiler-water-level gage is looked upon as a necessary evil requiring constant maintenance. Let's look at the record, as shown by plotting trends in boiler operating pressures for the years 1880–1950.

Before 1882 (the year the Pearl Street Station in New York went into operation), only anthracite-fired boilers were in general service in the East, and steam pressures were limited to 125 psig. With the advent of the early central stations using mechanical stokers and water-tube boilers, operating pressures increased to around 200 psig. During this period, and for some time thereafter, the vertical, round glass gage (Fig. 2) proved sufficient for the needs because boilers were low in height, the gage was readily visible, and there was no appreciable decrease in gage-glass life.

With demand for greater unit capacity, the possibilities of better thermal efficiency with higher pressure seemed sufficiently attractive to justify several 400-psig installations. Two problems were thereby created:

(*a*) The overall height of the boiler was increased, making the gage less visible from the floor.

(*b*) There was an appreciable decrease in gage glass life.

The first difficulty was solved by using an inclined gage (Fig. 3) in which the upper gage valve was placed close to the water column to allow clear vision. The second difficulty was partially met by sloping the top connection so that condensate would flow back to the water column, thus preventing erosion and corrosion of the glass.

A cross-section of a typical gage valve for that period is shown in Fig. 4. Note that the stem threads were exposed to steam and water and the body proper served to make the seat. Packing consisted of several rings of material suitable for the pressure.

Up to the early 1920's field experience indicated that tubular-type glasses should be limited to 400 psig; a flat-type "steel enclosed" glass or insert proved necessary for higher pressures.

In 1922, a few 550-psig boilers were put into operation. A typical design of flat glass insert, limited to approximately 600 psig (still in some use), is shown in Fig. 5. The glasses are mica-protected and held in place by heavy covers attached with studs and nuts. This required care in assembling to prevent uneven and undue loading, even though a cushion gasket was used between the glass and the cover.

Boilers began to appear in the late 1920's incorporating equipment such as water-walls, integral economizers and preheaters. Perhaps most important of all, operating pressure and temperatures increased considerably. In this period pressures leaped, in some cases, to 1200 psig, and a little later temperatures reached 900 F. One construction suitable for this and higher pressures is shown in Fig. 6. Instead of clamping the glass tightly between the cover plates and center section, the glasses in this "loose-window" insert are bolted in place so that they remain loose. The steam joint is made by clamping gaskets and mica against the center plate by means of the projecting surfaces of the cover plate surrounding the glass.

Another design (Fig. 7) is known by the trade name "Micasight." A substantial forged steel insert body provides the means of holding two windows of selected mica securely under slotted cover plates, fastened by bolted clamps. It is claimed that mica is a flexible material which will bend but will not break or blow out when properly assembled. Note that in this case glass is not used at all.

According to the March, 1952, issue of *Mechanical Engineering*, in 1950 at least one-fifth of the total capacity of large units installed were for pressures exceeding 1450 psi. During 1951 steam conditions for very large units (installed or ordered) ranged from 1670 psi to 2650 psi design pressure with 1000–1100 F temperature. At this writing some central stations are operating at pressures in excess of 2000 psig.

Careful consideration has been given to the design and to the material for each working part to meet the gage requirements for still higher working pressures. As a result of this study, one manufacturer developed a

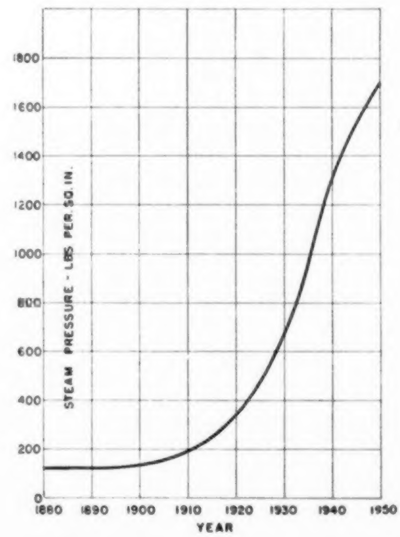


Fig. 1—Trends of boiler operating pressures for the years 1880 to 1950

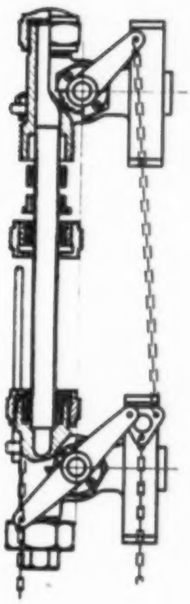


Fig. 2—Vertical round glass water gage

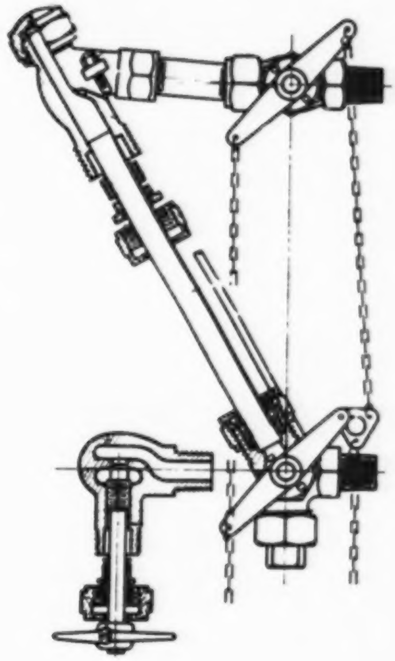


Fig. 3—"Se-Sure" inclined round glass water gage

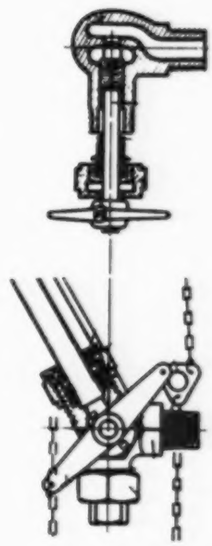


Fig. 4—Crossection—gage valve (low pressure)

"floating-assembly-pressure-sealed" insert which is shown in Fig. 8. Features of this design are:

1. A special molded, reinforced gasket fits into a stainless steel recess in the body, providing a tight joint without excessive tightening of the cover. This gasket is easily removed, when required.

2. Fastening covers, with shouldered cap-screws and stainless-steel spring cones limit the sealing load on the glass to a predetermined safe figure, and furnish a floating assembly. In addition, cones allow for slight variations in thickness of cover gasket and glass.

3. The mica (0.015 in. thick) used to protect the glass is hand-picked. A fact established in the laboratory was that ordinary visual examination is not always sufficient to assure good field performance; therefore, polarized light is occasionally used to check for stress patterns and planes of cleavage.

4. The manufacturer of glass realizes the need for supplying glasses resistant to chemical attack of boiler water.

Two important facts which determine chemical durability are alkalinity and temperature.[1] To increase the short-time strength of glass and increase the ratio between endurance limit and short-time strength, glasses are tempered. An additional advantage that accom-

[1] These conditions refer not so much to the water in the boiler as to water in the gage where both alkalinity, or pH value, and temperature may be appreciably different.

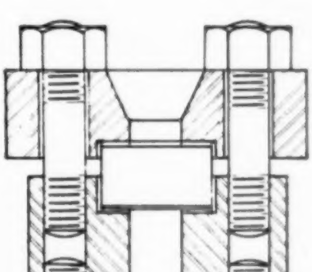


FIG. 5
YARWAY CONVENTIONAL FLAT GLASS INSERT

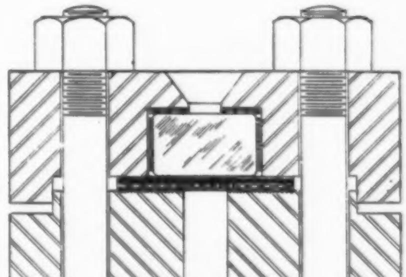


FIG. 6
DIAMOND LOOSE-WINDOW GAGE

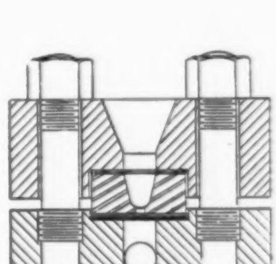


FIG. 7
RELIANCE MICASIGHT PRESS. TO 2000 PSIG

panies tempering is, if the glass fails in service, it will fail with an interlocking type of fracture.

Since glasses in present use show some sign of "strain release," particularly at pressures above 1500 psi, they should not be reused. One development under consideration by a glass manufacturer is a glass which will not undergo any appreciable strain release for pressures of the order of 2500 psi and would therefore possibly be suitable for reuse.

A typical "Welbond" gage valve construction, for use at 1500 and 2500 psi, is shown in Fig. 9. It will be noted that the outside yoke bushing is adequate in length, and the rolled-on hardened stainless steel disk mates with a stellite seat in the body, the packing box is deep and it uses a packing which has been proved in hard blowoff valve service.

A complete gage assembly, using "pressure-sealed" insert and "Welbond" gage valves, is shown in Fig. 10. Additional visibility is had by using, in effect, two independently staggered inserts. The lower flanged connection to the insert eliminates a stuffing box and assures maximum accuracy of the gage reading by eliminating a cold water leg. The upper flanged loop connection between the insert and gage valve allows full expansion and contraction of the various components. The tie bar provides circulation to keep the gage at a higher temperature and is the link between the gage valves. It also acts, to a limited extent, as a condensate guide.

Gage Illumination

With low-level boilers using round glass gages, it is not always necessary to employ an illuminator. If it is used, one or two bullseye illuminators, properly located, will suffice. However, for the higher pressure boilers it is necessary to illuminate the gage. One type, using a clear bulb in the bottom of the housing below the lowest point of water level visibility, has been in successful use for many years. The proper use of reflectors in it has given a readily observable meniscus over the entire visibility range of the unit.

A more recent type uses a 100-watt mercury-vapor lamp in place of an incandescent bulb. The superior penetration of the rays of this type of lamp cuts through turbid water deposits on the mica and extraneous light, so that the meniscus (at water level) shows like a brilliant white star over the entire range of visibility of the insert. This is important for direct viewing but even more so where a mirror system is required.

Transmitting Boiler Water Level to Eye Level

Since dependable readings are not easily made from points directly beneath vertical gages, or because of structural interferences, a system of mirrors may be used. Fig. 11 shows one system. It is popular because it permits placing the lower mirror some distance from the front of the boiler and is suitable for total reflecting distances up to 125 ft when used with a mercury-vapor illuminator. Under favorable conditions, by using a light shield at the gage and enclosing the reflecting system in ducts, it is possible to exceed the 125 ft maximum. The lower mirror, on a floor stand, is swiveled and has a vertical adjustment.

A recent development is the use of wired television. One real advantage is its flexibility insofar as location of the receiving screen is concerned. Its degree of acceptability will be determined from field performance.

Care of the Gage

1. First it is important to follow carefully the instructions issued by the gage manufacturer. They should be posted where readily available to maintenance personnel at all times.

2. Usually, disassembly of the gage does not require particular care but when disassembly is completed, the components to be used again should be carefully checked. For instance, a body groove which takes a gasket should be carefully cleaned to make sure the new gasket has a good surface against which to seal. Be careful that it is not marred in any way. The old cover gasket should also be carefully removed and gasket surface cleaned.

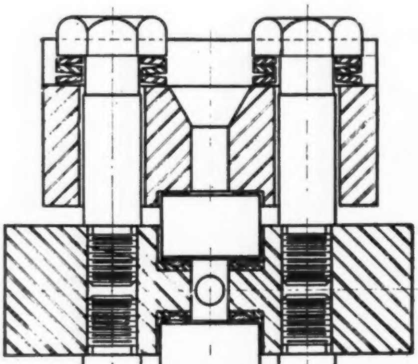


Fig. 8—Floating-assembly pressure-sealed insert

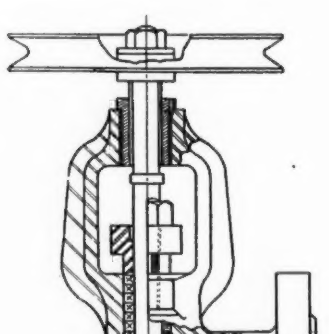


Fig. 9—Gage valve (high pressure)

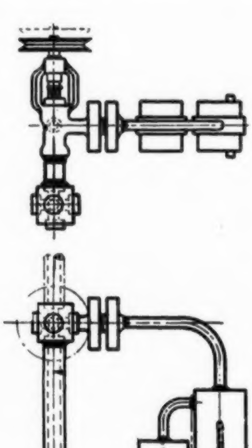


Fig. 10—Gage assembly with tie bar

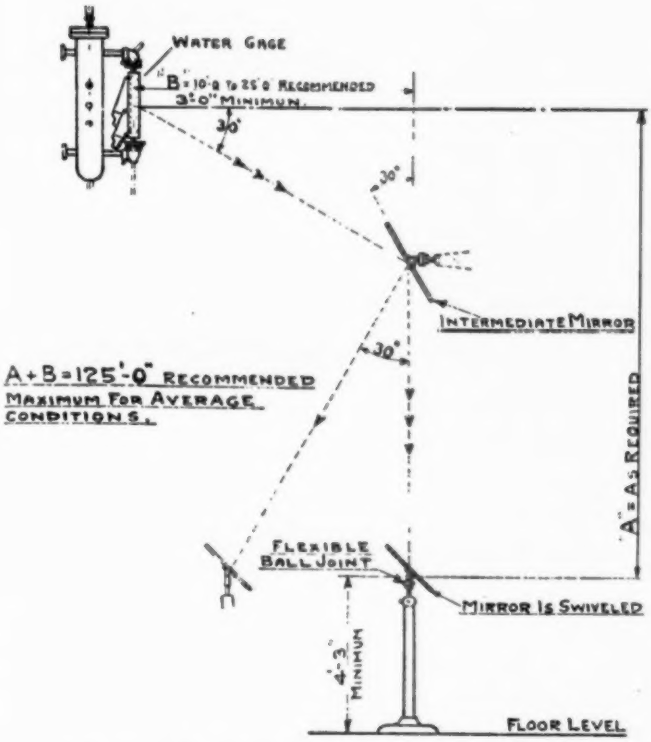


Fig. 11—One form of mirror transmittal system

3. Clean cap screw threads and paint with high temperature lubricant.

4. In reassembly, under no condition should graphite be used on a gasket surface. Under present operating temperatures carbonization and build-up can occur.

5. Do not reuse micas, glasses and gaskets. Although the glass may look perfect, it may not have the required physical properties.

6. Do not remove new components from their protective coverings until they can be immediately assembled in the gage.

7. If a slight preheat is required to obtain gasket flow, be assured the recommendation is made because experience has proved it correct.

8. Before and after assembly keep all metallic objects away from the glass.

9. Keep glands on gage valves adjusted to prevent leakage but do not excessively tighten. Lubricate stems and yoke bushings periodically. Keep valves open wide.

An Auxiliary to Observe or Record Boiler Water Levels

This article would not be complete without mentioning the "Remote Liquid-Level Indicator" which was developed within the past twelve to fifteen years, to supplement the gage proper. It furnishes eye-level readings or chart records of boiler levels on an instrument panel or at any other place, regardless of water column and gage location. As a manometric type of instrument, it is operated by the boiler water itself, using the pressure differential between a constant head of water and a varying head of water in the boiler drum and is completely independent of any external source of energy. The only connections between the boiler drum and indicator are two small tubes suitable for the pressure. The indicator uses a unique frictionless indicating mechanism which is never under pressure. A typical installation is shown in Fig. 12.

For pressures above 700 psig, it is furnished with a temperature compensating unit. When the boiler drum is at operating pressure, it furnishes a level reading which duplicates the gage reading. For all sub-operating pressures, it will read correctly for the normal position; slightly higher than gage for levels above normal; and slightly lower than gage for levels below normal. However, the small amount of over-travel of the pointer for suboperating pressures is cut in half because full correction is obtained at the mid-point and therefore any error above or below normal is halved.

Pressure compensation is another method which has been successfully used to give an indicator reading which duplicates the gage reading for all pressures, including the operating pressure, and for all positions of the level. Note that at the present time the gage reading is considered the correct standard but the gage installation on the drum affects its agreement or lack of agreement with the true level in the drum. If required, the indicator or recorder can be calibrated to read or record drum levels.

About eight thousand of these instruments, for pressures varying from 50 to 2500 psig, have been furnished. The performance of those in use has been field-tested over a period of years under various conditions and proved satisfactory.

Those who are responsible for the design and operation of steam generators know all too well the problems involving metallurgy, fabrication and boiler trim which have come with the use of these higher pressures. The boiler level gage manufacturer, for his part, has realized the need existing in the field. Continued technical research is a means to furnish engineers with partial answers; they are proved complete by field testing. This article shows that such research and field testing, on the part of the gage manufacturer, continues actively.

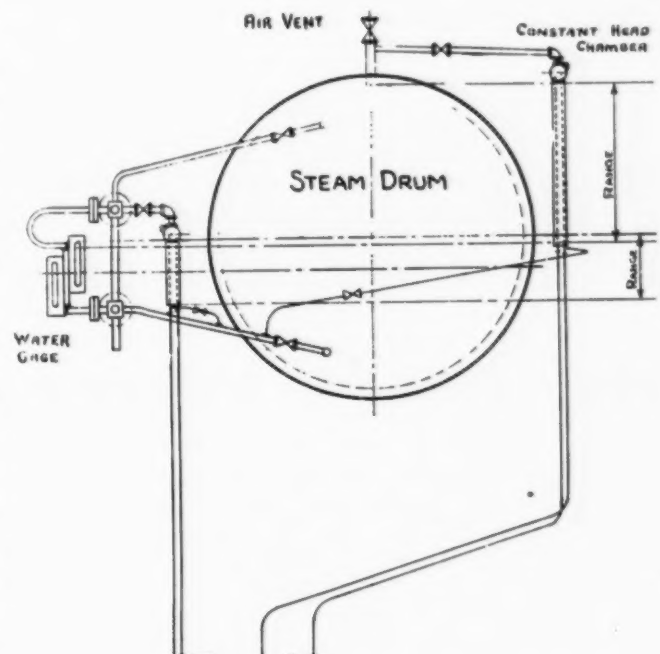
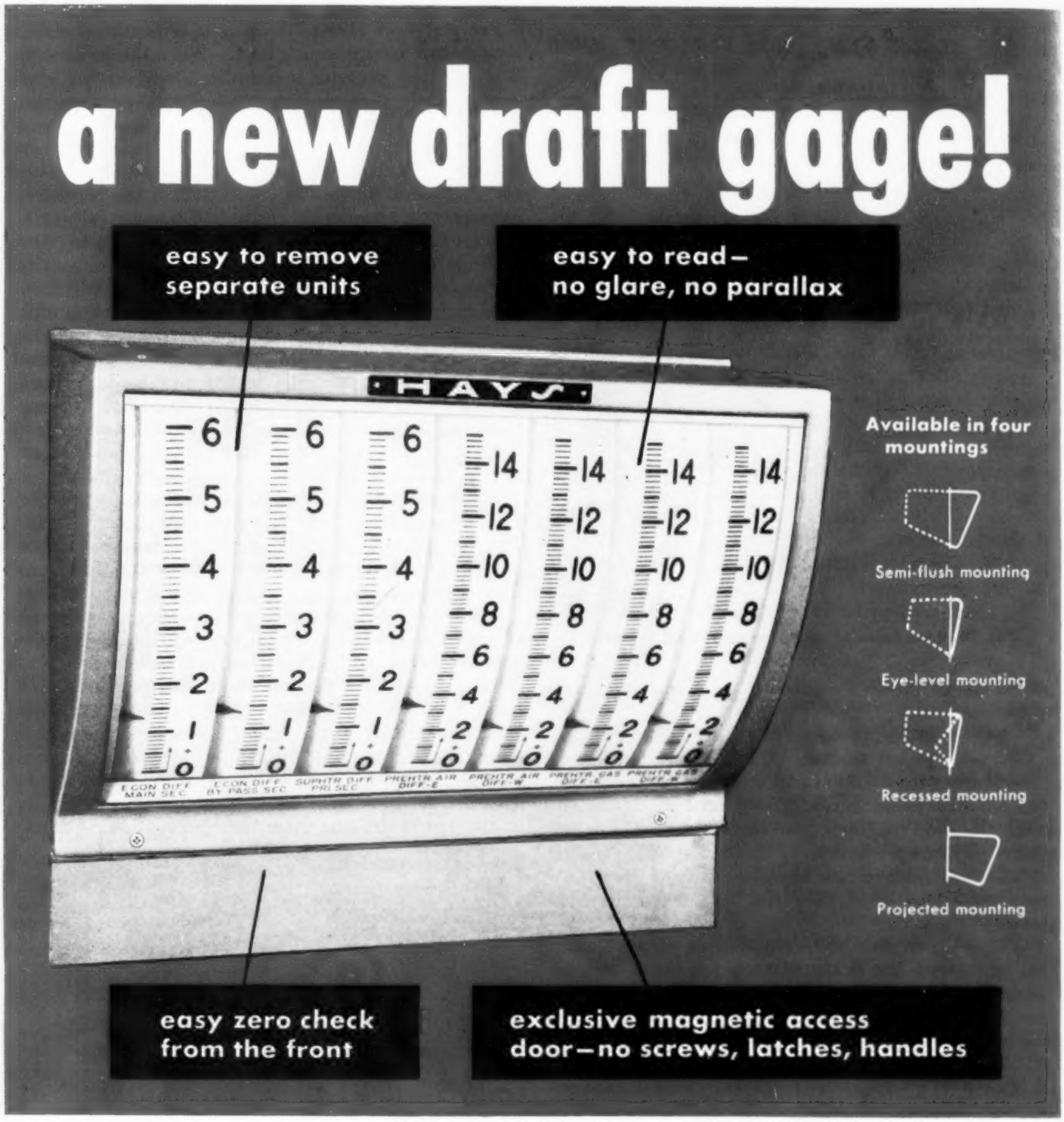


Fig. 12—Combined arrangement showing water level gage and remote liquid level indicator



the HAYS Vertiscale

You designed this draft gage! You asked for these features!
Accessibility from the front makes possible easy "one man" method of quickly checking zero. (The fast 3-way cock with test fitting is *standard* on the Hays Vertiscale).
Simple maintenance—individual units can be quickly removed for inspection or adjustment. Removal does not affect other units in the case, does not disturb calibration of unit being re-installed.
No parallax—design eliminates reflections regardless of viewing angle.
No glare—internal fluorescent lighting is standard.
You get all these values *plus* functional styling in the Hays Vertiscale draft gage!
Write today for full information on the Hays Vertiscale Bulletin 52-1060-210.

Automatic Combustion Control
Boiler Panels • Hays-Penn Flowmeters
Veriflow Meters and Veritrol
Gas Analyzers • Draft Gages
Combustion Test Sets • CO_2 Recorders
Electronic Oxygen Recorders

THE **hays** CORPORATION

MICHIGAN CITY 1, INDIANA

*External Boiler Tube Deposits**

By H. E. CROSSLEY

British Electricity Authority

Different types of deposits are discussed and correlations are suggested between the severity of trouble from these types and the amounts of various constituents such as chlorides, sulfur and phosphorous. Factors influencing the vaporization of mineral substances and condensation of these vapors on heating surfaces are also considered.

INORGANIC materials associated with British coals are mainly shales and iron compounds with small quantities of other minerals. The shales are complex aluminum silicates in combination with metals such as calcium, iron, sodium and potassium. The iron compounds are commonly pyrites and marcasite.

Fly Ash from Pulverized Coal Firing

In the flame the shale particles lose their combined moisture, and those that are ejected prematurely from the flame do not complete either the process of fusion or that of the evolution of moisture. These particles are white and rounded, the whiteness being due to the cavities formerly occupied by steam. The particles that continue in the flame tend to complete both processes.

The particles of iron minerals are converted to black rounded or spherical fly ash, the main constituent of which is magnetite (Fe_3O_4). Therefore, when the fly ash passes to collectors it consists of black and white spherical particles. If it settles on hot heating surfaces, some of the white particles change to pale pink which, after several hours of heating, may turn to the red form of ferric oxide.

Fly Ash from Stoker Firing

With stoker firing there is usually a larger range in sizes of fly-ash particles than with pulverized coal. The hollow particles with the former are partly due to the presence of calcium sulfate, as they left the fuel bed where the compound decomposed, evolving sulfur trioxide at temperatures above 2200 F. If the ash has fused when this temperature is reached, it is blown out into a hollow sphere by the sulfur trioxide. If the ash has not been fused, the particle is disintegrated.

The fly ash from stoker firing is derived mainly from mixed minerals; only a few particles are pure shale or iron residues, and the rest are mixtures of all proportions. Mixing of the minerals can take place in several ways. If the coal forms swelling coke, they mix while it is plastic; or even when the coal has no coking properties the minerals are mixed to some extent by sintering and slagging.

It is probable that on a traveling grate most of the fly ash comes from unburned coal from the front of the grate.

Stoker fly ash that passes straight through the system consists of spheres in a range of dingy tones, from colorless to stone, light brown, dark brown to black. The colorless particles are pure shale, the black particles magnetite and the intermediate tones result from the presence of various proportions of iron and shale. When the fly ash settles on a hot surface, the drab tones change to bright colors.

Sintered and Fused Deposits

In some boilers the first few rows of steam-generating tubes and, less frequently, superheater tubes, are fouled by deposits similar in composition to coal ashes. The constituents of typical ashes from British coals, according to King and Crosley, range from 25 to 50 per cent silica, as SiO_2; 20 to 40 per cent alumina, as Al_2O_3; zero to 30 per cent ferric oxide (Fe_2O_3); one to ten per cent calcium oxide (CaO); 0.5 to 5 per cent magnesium oxide (MgO); zero to 3 per cent titanium oxide (TiO_2); one to 6 per cent alkalies; and one to 12 per cent sulfur trioxide (SO_3).

When fly-ash particles have been lightly sintered, they are seen under the microscope to be little deformed in shape; but more intense sintering results in a strengthening of the joints between particles. The final stage is reached when the original particles completely lose their identities and form a fused slag.

Laboratory determinations of the sintering temperature of flue dusts have commonly shown 1500 to 1800 F. However, in the author's opinion, the usual laboratory determinations of fusion point have no value as a guide to slagging properties except in extreme cases where the ash is found to have a very low fusion point of the order of 1800 F, or a very high fusion point above 2500 F. This view is based on the following:

1. As prepared in the laboratory, coal ash is different in composition, manner of combination, and physical form from the fly ash that settles on parts of the boiler.
2. The fly ash settling on one part of a boiler often differs from that settling on another part.
3. Slagging in boilers begins with sintering and may be restricted to advanced sintering with no complete fusion.

The more direct method of obtaining significant information on sintering characteristics would be to carry out laboratory determinations on a sample of fly ash not already sintered and taken from the nearest position to the affected heating surface.

Vaporization of Mineral Substances

Evidence of this is found in the selective condensation of some of these vapors on heating surfaces, giving rise to the presence, in external deposits, of relatively large concentrations of substances which occurred as traces in the coal. This is very definite in boilers fired by stokers but less pronounced with pulverized coal. Factors contributing to this difference are: (1) the higher temperatures usually attained in stoker fuel beds; (2) the much shorter combustion time with pulverized coal; (3) the greater quantity of fly ash produced with pulverized coal firing; and (4) many inorganic compounds are more easily vaporized if they are reduced. Reducing conditions are pronounced in stoker fuel beds, whereas it is generally assumed that oxidizing conditions persist throughout a pulverized coal flame.

Boilers with slag-tap furnaces can be expected to provide marked evidence of mineral vaporization.

The opinion has been advanced in Germany that silica is vaporized from

* Excerpts from a paper to be presented on October 28 at a Conference sponsored by The Institute of Fuel (Great Britain) on "A Special Study of Ash and Clinker in Industry." Advance publication of the complete paper appeared in the September *Journal* of the Institute. Much of the work reported was carried out in association with the Boiler Availability Committee.

the shales in fuel beds as silicon sulfides, silicon monoxide, or just silica. Such vaporization is considered to be due to high temperatures, reducing conditions and the presence of iron pyrites. This belief is also based on the fact that there are marked increases in the ratio of silica to alumina in certain external deposits compared with the corresponding ratio in the ash of the coal.

While not denying that silica may be vaporized in some form in boilers, the author believes the increases in the silica-alumina to be due to loss of alumina from the external deposits and not to enrichment by silica.

Behavior of Coal Minerals

During combustion in a boiler the iron sulfides are oxidized and sulfur dioxide is evolved. Iron carbonate is thermally decomposed with the evolution of carbon dioxide. While spectrographic examination of flue gases has shown the presence of vapors of iron compounds, it has not been possible to show that deposits on heating surfaces have been enriched by iron from this source.

British coals contain from 0.01 to 1 per cent of chlorine, and the author has found that in several coals containing from 0.4 to 1 per cent, the chlorine was present almost wholly as a mixture of sodium and potassium chlorides occurring partly in the free state and partly adsorbed on the coal substance. It is advisable to use the chlorine content of the coal as an indication of the easily volatilized sodium and potassium present.

Phosphorus occurs in British coals, usually from 0.01 to 0.06 per cent as fluorapatite, $Ca_{10}Fe_2(PO_4)_6$. This readily loses fluorine, as hydrogen fluoride, when heated in moist air, but the residual calcium hydroxy-phosphate is extremely refractory and there is little loss of phosphorus, even at 3300 F under inert or oxidizing conditions. Under fully reducing conditions, however, the phosphorus is evolved as such at temperatures over 2700 F. There is evidence that with the semi-reducing conditions present in deep fuel beds vaporization of phosphorus begins at about 2900 F and that decomposition is about half completed at 3100 F.

When phosphorus is evolved from a fuel bed, it will be oxidized immediately by the overfire air to form pyrophosphoric acid ($H_4P_2O_7$).

Traces of about thirty elements can occur in association with the above-mentioned coal minerals.

Bonded Deposits

The commonest cause of external fouling of steam generating and superheating tubes is due to the bonding of fly ash in a matrix of inorganic salts, the main constituents of which are sul-

fates, and sometimes pyrosulfates of sodium and potassium, accompanied by iron and aluminum sulfates derived from reactions between the matrix and the fly ash. These deposits appear under the microscope as fly ash enclosed in whitish crystalline matter. The condition of the fly ash can be seen after dissolving the matrix in water or dilute acid. At temperatures below 1100 F sodium and potassium pyrosulfates have a slow solvent action on magnetic fly ash and form iron sulfates. Above this temperature a more rapid action takes place with the formation of hard red-black or black masses which are mainly ferric oxide.

When the matrix consists of pyrosulfates, the deposit can be expected to grow rapidly, as these salts are semi-molten while the boiler is in operation and fly ash collects on the sticky surface. The normal sulfates melt at much higher temperatures and can be expected to remain solid except on the hottest surfaces.

The author believes that the oxidizing action of the acid sulfates is a potential danger to boilers designed to attain a final steam temperature of 1050 F, if those boilers are subjected to the formation of such deposits. In most boilers the temperature of the outside of the superheater tubes is too low to permit the chemical slag reaction, but when the final steam temperature is 1050 F, the outside of some of the tubes will be at temperatures higher than 1050 F and the reaction could take place, resulting in tube wastage.

At a few British power stations deposits on steam generating or superheater tubes, although bonded, were not of the alkali-matrix type. On analysis these were shown to contain 10 to 35 per cent phosphate. Such deposits were probably due to the condensation of an acid of phosphorus. The absence of recognizable fly ash in such deposits was due to the formation of the phosphates of the metals in fly ash and silicophosphates from the silica present.

British boilers fired by pulverized coal have so far been free from phosphatic deposits, the powders removed from heating surfaces showing not more than one per cent phosphate. However, phosphatic deposits have formed on the surfaces of stoker-fired boilers. Stations so affected have been Battersea, Fulham, Upper Boat, Cardiff, Hayle, Plymouth, Portishead, Barking, Dunston and Dalmarnock. However, in all except two cases phosphatic deposits have been troublesome only on economizers. At Battersea, superheater tubes were seriously affected and less acute trouble of this kind was experienced at Fulham. As with alkali-matrix deposits, the dominant factor has been the character of the coal.

Operating Spreader Stokers*

By LEO J. COHAN

Combustion Engineering-Superheater, Inc.

IN selecting the boiler and stoker a realistic load factor is of prime importance. Ability to handle wide load variations is by no means license to handle unlimited load variations. Under normal operating conditions at grate heat releases below 125,000 Btu per sq ft, furnace temperatures are so low that smoking is almost inevitable.

Excess air at these low loads introduces further cooling and aggravates a smoky condition. Since leakage in a furnace is fixed at low loads, it becomes a greater percentage of the total air than at higher ratings.

Naturally, selection of equipment must be based on a maximum load condition, but it must be kept in mind that minimum requirements have to be met. It would be a simple matter to increase maximum grate heat releases to maintain a higher minimum if it were not for increased carryover, decreased efficiency, and increased unit maintenance.

Many plants that fall into the category of code violators would be model plants if it were possible for them to utilize small units operating within acceptable heat release limits, instead of being handicapped by oversized equipment. Load ranges in the ratio of 8 or 9 to 1 are practical but this can often only be accomplished by resorting to manual operation. Close steam pressure control is difficult to achieve under these circumstances.

Frequency of load variation is another important factor. For completely automatic operation, where efficiency and an acceptable stack discharge is a must, a ratio of 4 or 5 to 1 is reasonable.

Controls and Instrumentation

One factor that has led to the rise of the spreader stoker is its flexibility. The thin active fuel bed makes this possible, but the proper proportioning of air to fuel, with a regulated furnace draft, is critical. Whenever there is a load change, proper proportioning must be accomplished in minimum time if smokeless operation is to be maintained.

Several types of control can be utilized effectively with a spreader stoker. The positioning type adjusts the fuel-air ratio to conform closely with the boiler output. Usually the actuating impulse is from the main steam header. With a given load change a corresponding pressure change occurs, which establishes a definite position for the fuel feed and air-flow regulator. This type of control will offer reasonable approximations of a correct fuel-air ratio as long as fuel characteristic remains constant. Its advantages are: (1) simplicity and reliability; (2) more easily understood by less skillful operators; and (3) low initial cost.

These advantages make the positioning control well suited for smaller industrial plants employing operators of limited experience. Its disadvantages are: (1) necessary readjustment of linkage with every major coal change, and (2) efficient operation throughout wide ranges is largely dependent upon the experience and ingenuity of personnel placing the equipment into initial operation.

Where efficiency is required throughout a wide load range, another type of control is desirable. Large industrial plants and utilities employ the metering or proportioning type in which the gas or air flow is metered through the boiler and draft loss is balanced across an actuator. The actuator regulates coal feed and air flow to the stoker in accordance with previously made calibrations. Advantages of this type control are: (1) higher average efficiencies throughout average load ranges, and (2) little or no adjustment is required for major fuel changes.

With both systems some means of controlling furnace draft is necessary. This can easily be accomplished by an independent furnace-draft regulator.

Instrumentation is very desirable to facilitate proper adjustment of controls. Of prime importance is a furnace-draft indicator, followed closely by uptake draft and undergrate pressure gages. Steam-flow meters, incorporating an air-flow indicator and recorder, play an important role as a firing guide. Smoke indicators and CO_2 recorders psychologically go a long way in maintaining high operating standards.

However, no control system can duplicate intelligent thinking and reasoning on the part of an operator. A neglected control system is sometimes worse than no control system.

Coal and Ash-Handling Equipment

Of prime importance is a continual and uninterrupted supply of fuel delivered uniformly to the stoker without segregation. To avoid serious segregation consideration should be given to the manner of loading the bunker. Swing spouts or a weigh larry provide an excellent means.

Ash-pit construction has a definite effect on air pollution. Sufficient storage capacity should be provided to permit removal of ashes during low-load operation.

Adequate provision for mixing of combustible gases and air at temperatures high enough to complete combustion is a basic requirement. In the simple archless furnace, in which a spreader stoker is usually set, some external impetus is necessary to provide turbulence. High-pressure overfire air or steam jets mix the gases and air near the grate line, hence some of the time necessary to complete combustion is gained. Physical proportions of the furnace must be such as to allow for adequate linear flame travel and low vertical gas velocities.

Performance of Typical Installations

An 80,000-lb per hr C-E steam generating unit fired by a C-E continuous-ash-discharge spreader stoker was given a 24-hr acceptance test in accordance with the ASME Test Code. The boiler is of the two-drum type with plain waterwalls, steel-encased setting and equipped with an economizer. Initial operating pressure is 275 psig. The continuous-discharge stoker is 14 ft wide by 16 ft overall length and cinder reinjection is taken from the boiler passes and the economizer hopper.

The coal was an Indiana bituminous having a proximate analysis, as fired, of 10.5 per cent moisture, 35.2 per cent volatile, 41.8 per cent fixed carbon and 12.5 per cent ash, with a heating value of 11,103 Btu per lb. The size consist was 100 per cent through $1^1/_4$ in. round-hole screen, 4 per cent on 1 in., 16.6 per cent on $^3/_4$ in., 47.8 per cent on $^1/_4$ in., and 31.6 per cent through a $^1/_4$ in.

An overall efficiency of 85.46 per cent was attained on a metered basis, and 83.94 per cent on a heat-balance basis. Both these figures exceeded the guarantee of 80.7 per cent.

Unburned combustible in the ash pit was 4.7 per cent and that in the cinder collector refuse 30.5 per cent. Resulting carbon losses were 0.61 per cent in the ash-pit refuse and 1.61 per cent in the cinders and gases leaving the economizer.

At the end of the 24-hr test the steam output was increased by 25 per cent. After conditions became stable, the stack discharge was restored to that maintained throughout the test run, namely a Ringlemann No. 1. The fuel bed remained light and porous with no evidence of clinker formations during the overload operation.

Similar tests were conducted on a unit rated at 150,000 lb per hr with Illinois bituminous coal having moisture 14.9 per cent, volatile matter 33.1

* Excerpts from a paper presented at the 9th Semi-Annual Meeting of the East Central Section Air Pollution Control Association of America, Louisville, Ky., September 19, 1952.

per cent, ash 10.6 per cent, heating value 10,500 btu per lb. Cinders are reinjected from the last boiler pass.

At rated capacity the calculated overall efficiency was 83.3 per cent as compared with a predicted efficiency of 80.1 per cent.

At the time performance tests were being conducted, a set of dust loading data was collected. Results indicated the stack emission to be within the limits specified by the various codes and city ordinances and well below the proposed model code of the ASME which specifies limits of 0.85 lb per 1000 lb of gas.

Ductile Iron Explained

It was about three years ago that, after extensive research at the Bayonne, N. J., Research Laboratory of The International Nickel Company, it was learned how to produce a cast iron so ductile that it can be bent, twisted and resist shock, yet possess several times the strength of ordinary gray iron. These properties result from its graphite being in the form of spheroids produced through use of magnesium in the process, in contrast with the flake graphite in gray cast iron. This product, designated as "Ductile Iron," bridges the gap between ordinary gray iron and cast steel, and is now being applied to equipment in various industrial fields, particularly where complex shapes with high mechanical properties are required. It is said to have good machinability, a hardness of 140 to 550 Brinell, and to maintain its strength up to about 800 F. Its cost is about one-sixth that of aluminum.

One of many new products made possible by utilizing the properties of Ductile Iron is pipe for city water lines where the increased strength permits thinner wall section. It is also expected that such pipe will find application in the transmission of fluids and gases as it expands under high pressure instead of bursting. In one test gray iron pipe failed and shattered under 2400 psi hydrostatic test whereas a Ductile Iron pipe, after expanding, failed at 5300 psi without shattering. In all there are now nearly 200 companies licensed for the manufacture of Ductile Iron, here and abroad.

In order to bring the engineering press up to date on these developments, The International Nickel Company was host to a group of technical editors at its Bayonne Research Laboratory on September 25 where various tests of Ductile Iron were conducted, its casting demonstrated and numerous commercial products shown in which it is employed. Among these were crankshafts and camshafts, pump and compressor castings, water gage parts, gears, engine pistons and heads, oil-well valves, casings of various types, pipe-wrench frames, stoker grate bars and many applications in the automotive and aviation fields, as well as road-building machinery.

Properties

Mechanical properties, as cast, range from 85,000 to 105,000 psi tensile strength and 2.5 to 10 per cent elongation. When annealed, the yield point is 50,000 to 60,000 psi and the elongation 17 to 23 per cent. When normalized and drawn, the tensile strength (air-cooled from 1600 F) ranges from 135,000 to 138,000 psi with a yield strength of 89,250 to 95,000 psi; elongation of 7 to 8 per cent in 2 in. When oil quenched the tensile strength is increased to 152,000 psi.

Normally Ductile Iron contains, in per cent, 3.5 total carbon, 2.3 silicon, 0.35 manganese, 0.50 phosphorus, 0.01 silicon, 1.25 nickel and 0.06 magnesium, although this is varied to give the desired qualities of strength and ductility. In welding, an iron nickel electrode is employed.

Business Notes

Johns-Manville Corp. has appointed John B. Jobe assistant district manager of its Industrial Products Division at Los Angeles.

Copes-Vulcan Division of the Continental Foundry & Machine Co. has named Carl Grimes & Co., of Des Moines, Iowa, as its representative for Copes boiler feed control, Hi-Lo water alarms, pressure-reducing stations and desuperheaters in the state of Iowa.

Hagan Corp., Pittsburgh, has appointed George O. Manifold, professor of mechanical engineering at the University of Pittsburgh, as director of education to implement a new educational program for Hagan personnel and other engineers sent to the company for study of Hagan combustion and process controls.

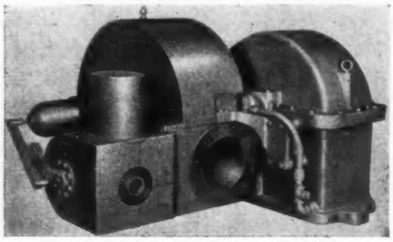
The Carborundum Co. has appointed William J. Kingsley to the position of assistant general sales manager. He joined the sales engineering department of the Company in 1922.

Allis-Chalmers Mfg. Co. has set up a new regional field service organization which will handle all service, repairs, breakdowns and adjustments in the field. It will be operated under the direction of Vice President C. W. Schweers with regional supervisors in Chicago, Cleveland, New York, Atlanta, Dallas and San Francisco.

NEW EQUIPMENT

Reduction Gears

Elliott Co., Jeannette, Pa., announces a new line of high-speed reduction gears for mechanical drive turbines, which are available in built-in or coupled designs. Both designs feature precision-hobbed double-helical gears, liner-type



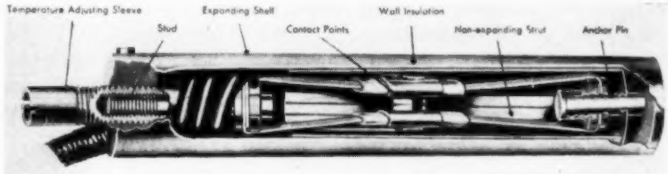
sleeve bearings, special Kingsbury-type shaft seals, and self-contained forced-feed lubrication system. The new line of gears is offered in gear ratios up to 5:1 for built-in units; up to 8.5:1 for the coupled design.

Corrosion Protection

Positive protection against rust without costly coating is the chief characteristic of VPI, a volatile amine nitrite now being marketed by the Shell Oil Co., 50 W. 50th St., New York 20, N. Y. This powder-like substance is also helping to reduce the cost of packaging metal parts, protecting them during storage and shipment or between processing steps. The product is required in very small quantities and protects by giving off a vapor which is carried to all surfaces of the metal and condenses to provide a thin film. VPI can be applied by placing it in crystal form in a package containing parts to be protected by blowing the crystals into an area, or by dissolving it in a water or alcohol solution and spraying it on the parts or products to be protected. Parts need not be coated when VPI is used, thus avoiding the necessity of stripping or cleaning parts, products and surfaces. In addition to preventing rust, it also arrests corrosion at any advanced stage.

Precision Thermostat

The precise temperature control essential to accurate analysis of flue gas is provided by a Thermoswitch manufactured by Fenwal, Inc., of Ashland, Mass., for use in an automatic oxygen-excess air analyzer. The instrument operates on the catalytic-combustion principle, utilizing a noble metal catalyst-filament. The flue gas, introduced at a constant rate, is mixed with a controlled quantity of vaporized standard fuel, and the resulting mixture is burned by the catalyst-filament. The heat liberated by this combustion varies with



the oxygen content of the flue gas. Because the filament forms one leg of an a-c measuring bridge, variations in heat unbalanced the bridge and result in the operation of a motor-driven slide wire to balance the measuring circuit. The motor also drives a recording pen which provides a continuous graphic record calibrated in either "per cent oxygen," "per cent excess air," or "mixture ratio."

The rapid response of the thermostat results to a large extent, because the cylindrical outer shell, which houses the switch contacts, is actually part of the temperature-sensing mechanism. Therefore, because the shell is in direct contact with the constant temperature block, the thermostat starts to respond immediately to any temperature variation. Temperature change causes a relatively greater elongation (or contraction) of the shell than of a pair of internally mounted low-expansion struts and the resulting force on the struts causes the switch contacts to actuate.

Paint Remover

A new type electric paint remover, designed to remove paint quickly and economically through the use of radiant heat, has been announced by the Industrial Heating Department of the General Electric Co., Schenectady 5, N. Y. Developed for both professional and home use, the new paint remover consists of two skids under which is mounted a G-E Calrod tubular heater rated at 1000 watts, 115 volts. When the device is slid along a painted surface, the heat from the unit causes the paint to soften and blister and it can then be removed with a putty knife. Old paint can be removed continuously

as fast as the operator can scrape it off. The skids keep the heat a safe and constant distance from the painted surface.

Diaphragm Regulating Valve*

A double-seated diaphragm regulating valve for use with control instruments has been announced by Leslie Co., 173 Delafield Ave., Lyndhurst, N. J. The new valve, "Class DV," has been developed to meet features required by various process industries and provides as standard equipment, features heretofore only obtainable in expensive, specially designed valves. Among the principal features of the new valve is its "flow-line" contoured body which has been designed to provide ISA standard face-to-face dimensions with the highest capacity, lowest turbulence and body pressure drop. Renewable in-

terchangeable seat rings is another important feature of the new valve. These rings are machined so accurately that they can be removed and replaced without removing the valve body from the pipe line. This simplified maintenance eliminates the expensive practice of removing the body from the line and setting it up in a lathe to replace the seat rings. It also eliminates elaborate grinding operations at high temperatures. The new valve is available in sizes from $1^1/_2$ to 10 in. up to 600 psi, with screwed and flanged ends.

* Inadvertently the wrong illustration was used on page 66 of our August issue. We are therefore repeating the new equipment announcement of the Leslie Diaphragm Regulating Valve.

Joint Fuels Conference

Philadelphia will be host to the Fifteenth Annual Joint Fuels Conference of the Fuels Division, ASME, and the Coal Division, AIME, which will be held at the Bellevue-Stratford Hotel, October 30 and 31.

PROGRAM

Thursday, Oct. 30

Morning Session

DOMESTIC STOKER SYMPOSIUM

Co-chairmen: Howard A. Herder, Sahara Coal Co., Chicago
Carroll F. Hardy, Appalachian Coals, Inc., Cincinnati

Panel Members

"Service and Operating Experiences on Two Models of Preoxidizing Domestic Stokers" by Prof. T. S. Spicer, Pennsylvania State College

"Comprehensive Studies of Draft Arrangements for Domestic Stokers" by Charles H. Sawyer, Koppers Coal Division of Eastern Gas and Fuel Associates

"New Type of Domestic Anthracite-Burning Equipment" by Dr. Raymond C. Johnson, Anthracite Institute

LUNCHEON

Presiding: W. E. Reaser, Chairman, Fuels Division, ASME
A. L. Barrett, Chairman, Coal Division, AIME

Film Presentation: "Powering America's Progress" by Bituminous Coal Institute

Afternoon Session

Co-chairmen: F. C. Messaros
S. L. Bunting

"Use of Anthracite in the Sunbury Station" by C. H. Frick, Pennsylvania Power & Light Co.

"Domestic Use of Anthracite" by R. C. Johnson, Anthracite Institute

7:00 p.m. Banquet

Toastmaster: Julian E. Tobey, President, Appalachian Coals, Inc., Cincinnati

Speaker: Dr. A. A. Potter, President, Bituminous Coal Research

Subject: "Let's Look Ahead"

Percy Nicholls Award to: Dr. H. F. Yancey, U. S. Bureau of Mines, Seattle, Wash., presented by A. W. Thorson

Friday, October 31

Morning Session

"Some Fundamental Principles Applying to the Design and Operation of a

Fine Anthracite Coal Plant at the Coaldale Colliery" by Wm. T. Turrall and M. J. Cook, Lehigh Navigation Coal Co.

"Use of Oil in Coal Preparation" by John L. Stewart, Ashland Oil and Refining Co.

"Mechanics of Oil Treatment of Coal" by C. E. Berry and J. H. Dawson, Viking Machinery Sales Co.

"A New Method of Spraying Oil at the Georgetown Plant" by Alfred F. Meger, Hanna Coal Co.

Afternoon Session

Co-Chairmen: J. B. Harlow
D. J. Mosshart

"A Study of the Problem of Coal Freezing" by Dr. C. C. Wright and E. E. Petersen, Pennsylvania State College

"Cost of Coal and Ash Handling Equipment" by C. A. Marshall, Fairmont Coal Bureau

"Cyclone Dust Collectors for Boilers" read by F. C. Messaros

This year a special feature has been added to the program to interest young engineering students in the importance of fuels. Student members from nearby universities will be invited as guests at the banquet. Members of ASME and AIME will be asked to pay for their tickets and be their hosts.

New Catalogs and Bulletins

Any of these may be secured by writing Combustion Publishing Company, 200 Madison Avenue, New York, 16, N. Y.

Industrial Instrumentation

"Fundamentals of Instrumentation for the Industries" is the title of a 126-page booklet prepared by the Brown Instruments Division of the Minneapolis Honeywell Regulator Co. It covers the fundamentals of measurement, control and transmission of variables encountered in industry. Typical applications are also discussed.

Pressure-Seal Valves

A 16-page catalog describing Pressure-Seal stop, check and non-return valves has been issued by Edward Valves, Inc. Separate spreads in the booklet give complete descriptions, design characteristics and dimensional details on valves which are available in sizes from $2^1/_2$ to 14 in. and in 600, 900, 1500 and 2500 lb pressure classes.

Controller

The Swartwout Company has prepared a six-page bulletin on the Autronic Controller. In addition to a brief résumé of its basic operating principle the bulletin gives a detailed description of the controller, with the aid of photographs, schematic diagrams and dimensional drawings.

Steam Traps

Armstrong Machine Works has issued a revised edition of its Bulletin 213, a condensed catalog on steam and air traps. It contains a sequence of diagrams explaining the operating principle and design features of inverted bucket traps. Prices, physical data and other details concerning cast semi-steel steam traps, forged-steel steam traps, and ball float air and air relief traps are also included.

Welding Electrodes

A 49-page, pocket-size booklet describing the application, chemical analysis and mechanical properties of General Electric Welding electrodes has been announced as available. Designated as GED-1634, the new booklet includes an electrode trouble-shooting chart, a chart which specifies the member of electrodes per pound, and an explanation of the significance of the AWS nomenclature.

Control Valve Design

"New Techniques in Control Valve Design" is the title of a 16-page technical bulletin written by R. B. Werey, president of Conoflow Corp. The bulletin covers in concise and readily understandable language a review of conventional control valves and a look-see into future designs. It is well illustrated and explains the underlying reasons for present and anticipated future designs.

Industrial Insulation

A 20-page illustrated catalog published by the Baldwin-Hill Co. describes insulating materials which cover the complete temperature range from −150 to 1800 F. Complete with thermal conductivity diagrams and heat-loss charts, this catalog also shows list prices subject to trade discounts. Brief application descriptions, together with typical uses, sizes, packaging and densities, are also a part of the catalog.

Soot Blowers

Bulletin 1002 illustrates and describes Vulcan long-retractable soot blowers with air and electric drives These are suitable for travels of more than 20 ft and blow with steam or air without change in original equipment. Rotating and traversing speeds are independently adjustable.

Turbidity Recorder

The Ess Instrument Co. has made available Bulletin No. 604 which covers a turbidity recorder, TR-6, suitable for measuring accurately the amount of light cut off by undissolved substances suspended in fluids. Information relative to operating principles, range of application, etc., is included along with technical sketches illustrating various chambers, indicators and recorders.

Chemical Proportioning Pumps

An eight-page bulletin made available by %Proportioneers, Inc.%, provides information on the heavy-duty Chem-O-Feeder. It gives specifications and features of these small proportioning pumps which may be equipped with one, two or three measuring chambers for capacities up to 57 gph.

Centrifugal Pumps

Ingersoll-Rand Co. has released a 16-page bulletin covering general purpose centrifugal pumps of the cradle-mounted type. It covers five basic cradle groups and 17 corresponding pump types, their capacities, horsepower ratings and uses. There are also two pages which cover pump dimensions and a table of performance under 60-cycle use.